

Karma (PTY) LTD
Instrumentation & Control



**THE RIGHT
PRODUCT FOR
THE RIGHT
APPLICATION.**



MEMBER OF  **SAIMC**
INSPIRING AUTOMATION

B-BBEE COMPLIANT



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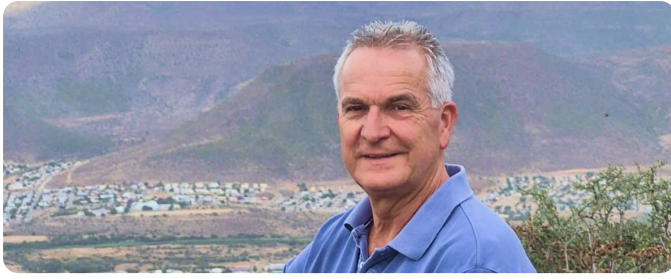
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**YOUR TRUSTED,
RELIABLE AND
SPECIALIST SUPPLIER
OF PROCESS CONTROL
AND INSTRUMENTATION
EQUIPMENT.**

Indemnity:

Karma Instrumentation and Control product catalogue provides an overview of products provided and serviced by us. This catalogue only serves as a guide and information can be adapted and changed by product suppliers without prior notice. ***It is the customers responsibility to confirm information and specifications.***



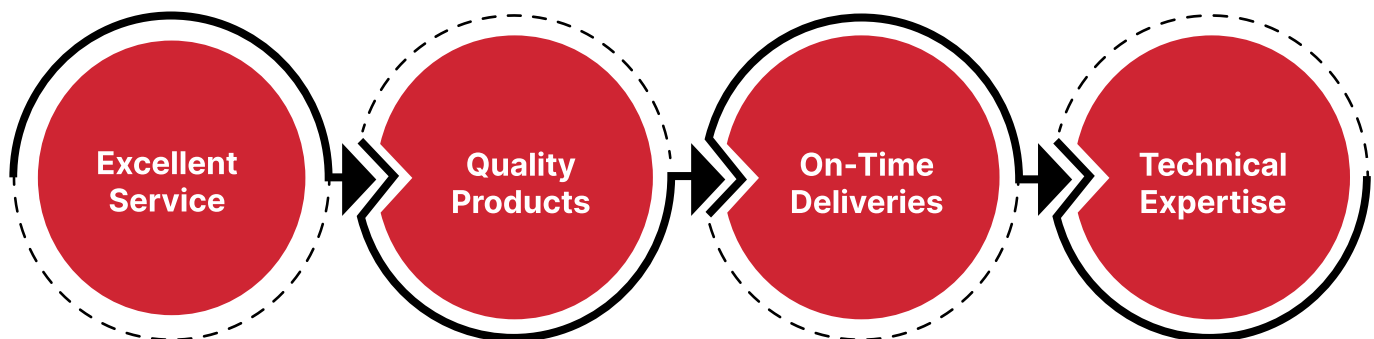
Richard Georg Mayr started his career in 1978 studying Process Control and Automation and completed his Engineering Diploma in 1982. In his earlier years, Richard worked for some well-known International German Companies (Hartmann & Braun, P.C.I, Siemens), before starting his first business venture specialising in Heating and Temperature Control in 1994 (Thermacon Manufacturing).

His career and knowledge grew immensely in the Process Control and Automation field whilst working for these multinationals,

which in turn enabled Richard to move into the upper management structures within those organisations. This facilitated Richard's opportunities to further his studies in the financial and management fields. In 1988, Richard completed his UNISA SBL Management Development Programme (Cum Laude) which spearheaded his career to reach top management within Hartmann & Braun.

Richard worked several more years with a Heating Specialist Company (Director of Unitemp) adding immense value and growth to its sales. After working more than 12 years in the Heating and Temperature related sector Richard decided to move back into the field of Process Control and Automation in 2011. Richard subsequently partnered with Herbert Karolius from Atlas Industrial Systems to start **Karma Instrumentation and Control**.

KARMA INSTRUMENTATION & CONTROL PRIDES ITSELF IN AFFORDING ITS CLIENTS:



OUR PHILOSOPHY IS TO “OFFER THE CLIENT THE RIGHT PRODUCT FOR THE RIGHT APPLICATION”

Karma Instrumentation and Control is supported by a team of highly qualified Engineers/ Technicians and Artisans who specialise in the field of instrumentation and electrical related work. The team is capable of project design, installation and commissioning from the original concept to final handover.

The processes the company is involved in are primarily instrumentation, electrical and process related. The projects can be small in nature right through to medium sized projects where the team will design and ensure that the final implementation is signed off according to the customers specifications.

THE RIGHT PRODUCT FOR THE RIGHT APPLICATION.

SANAS ACCREDITATION

Karma Instrumentation and Control offers full SANAS certification together with its partners on flow, temperature, mass, volume, humidity and pressure. SANAS (South African National Accreditation System) is responsible for carrying out accreditations in respect of conformity assessments mandated through the Accreditation and Conformity Assessment, Calibration and Good Laboratory Practice Act (Act 19 of 2006).



Karma Instrumentation & Control

We are supported by a team of highly qualified engineers who specialize in designing, wiring and commissioning electrical and process control panels from small to medium size turnkey projects. Our team of System Integration Engineers completes our package of services by programming, designing, installing and commissioning PLC systems to meet customer requirements.



Karma Instrumentation & Control

Our key markets include food and beverage, iron and steel, cement, glass, tobacco, dairy, agricultural, pharmaceutical, cable, rubber, textiles, oils and tars, power generation, pulp and paper, mining, water treatment, plastics and printing, metal processing, gas and chemical.



Karma Instrumentation & Control

We source our products from reputable suppliers who originate from Europe, America, Australia and the East. All the products are fully backed up and/or repaired by our service technicians. In addition, many of our products are suitable for Hygienic, Explosion Proof (Ex) and/or Intrinsically Safe (IS) conditions. Product training is offered to all our clients if the need arises.



Karma Instrumentation & Control

We also offer SANAS calibration and verification for pressure, load cells, temperature, flow, mass & volume, humidity, and handheld test instruments, together with our accredited SANAS partners.



Karma Instrumentation & Control

We service and repair all brands of globe, ball, butterfly and gate valves including electromagnetic and electronic positioners, load cells, Siemens PLC's, VSD's and all products we sell.



PROJECT MANAGEMENT FROM CONCEPT TO FINALISATION

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Projects completed:

- ATEX heating and curing oven for the testing of fluorine coated containers.
- Scanner to measure and control moisture on rollers in the pulp and paper sector.
- Effluent weir channel control systems to measure water flows and monitor liquid analysis on ph and conductivity.
- Designing and assembling electrical control panels for specialised air products.
- Installation and commissioning of annubars and DP transmitters for mass steam flow measurement.
- Service Level Agreements (SLA's) on Siemens PLC hardware and software related equipment with 24 hour services with various companies.
- Complete refurbishment of pipe work and valve automation in a processing plant.
- Supply, Fitment and Commissioning of Vortex flow meters for steam flow measurement.
- Supply of Coriolis mass flow meters including commissioning thereof.
- Data capturing and monitoring using Core View Software.

PROJECT MANAGEMENT FROM CONCEPT TO FINALISATION



Karma Instrumentation and Control are the specialists in the supply of Process Control and Measuring equipment.

We support system integration from software to hardware. Our solutions work with what you have. Onsite technical back up and software programming for Siemens and Delta PLC's. Installation and commissioning of our own products for both new and existing plant expansions.

We offer repairs on Siemens HMI's, UPS's, VSD's, DC Drives, PLC's and PLC cards. Our work is our pride. We calibrate, test and certify our work onsite or off site for temperature, flow, mass, volume, humidity, handheld measuring instruments, pressure, and load cells.

Process control is just another one of our services. From design to test, give us your specifications and we will design, wire and manufacture accordingly.

The company is a B-BBEE Compliant contributor, has a Letter of Good Standing and all other statutory requirements in place.

Karma Instrumentation and Control offers "Service Level Agreements" (SLA's) on Siemens and Delta PLC's.

» www.karmainstrumentation.co.za





TRAINING

In-house and on-site training is offered on all our products listed as below:

The training encompasses both theoretical and practical applications.

- Siemens and Delta PLC's

- Flow measurement

- Temperature controllers and associated products

- Humidity and related applications

- Angular transducers

- Valve automation and related

- Water treatment products and solutions

- Process control and related applications

ANGULAR/DISTANCE/POSITION/INCLINATION MEASUREMENT

Displacement measurement is the process of tracking and quantifying the change in position from a known reference or starting point. It identifies both the magnitude and the direction. They can be both contact and non-contact sensors. Laser type are typical non-contact types whilst contact types include: magnetostrictive, encoders, draw wire, rod or linear resistive, magnetic, tape and cable types.

Construction is based on either rotational or a resistive strip which will result in actual linear measurement of travel.

Absolute and incremental encoders are widely used in all forms of displacement measurement with accurate positioning monitoring being provided.

The scanning head MR magnet angular displacement encoder is extremely accurate and easy to install. The inclination sensors offer contactless, wear free and absolute measurement of tilt angles between 0 and 180 Degrees.

Outputs vary from current and voltage signals to SSI, Profibus, Profinet, CanOpen and resistance.



ANGULAR/DISTANCE/POSITION/INCLINATION MEASUREMENT

Typical applications include: presses, shears, robots, injection moulding machines, motion control, medical devices, ranging instruments, liquid level detection and position control.

Encoders (Incremental, absolute, rotary and linear) are rotational devices which measure displacement, speed and direction via rotational movement.

An encoder is a device that converts mechanical motion into an electrical signal and is commonly used in motors, automation equipment and motion control applications.

These encoders have many different ordering options available depending on the application:

- Shaft size
- PPR
- Varying Outputs
- Hollow shaft
- IP Ratings
- Optical sensing



BLOCK CHUTE / TILT DETECTORS

A blocked chute detector is an industrial sensor used to monitor material flow and prevent blockages in conveyor chutes, hoppers and bins. When a build up is detected, the device triggers an alarm and automatically stops the conveyor to prevent severe equipment damage, material spillage and costly production downtime. These detectors are primarily used in heavy industries such as mining, aggregate processing and manufacturing. Because the operating environments are notoriously harsh, often plagued by dust, extreme vibration and flying debris four main technologies are used.

Microwave/Radar detectors: These emit a continuous low power microwave beam across the chute. When material blocks the chute the beam is obstructed, triggering an alarm. These are highly effective microwave signals because they can easily penetrate heavy dust and thick material build up on the sensor heads.

Tilt switches: A mechanical switch is hung inside the chute at a designated level.

If material builds up from the bottom, it pushes and tilts the switch beyond a specific angle (usually 35 degrees) which opens the electrical contacts and stops the conveyor.

Capacitive switches: These use electrical capacitance to detect the presence or absence of material. As product levels rise and touch the probe, the capacitance changes and trips the sensor.

Acoustic switches (Gamma). These use sound waves to detect blockages, while gamma switches utilize non-contact radiation to measure levels from the exterior of the vessel.

Pneumatic air knockers are automated compressed air-powered hammers used in manufacturing and processing. They deliver sharp localised impacts on the outside of hoppers, silos and chutes to dislodge stuck compacted powders and bulk materials, preventing blockages like bridging and rat holing.





SANAS ACCREDITATION

Karma Instrumentation and Control offers full SANAS certification together with its SANAS Accredited partners on flow, temperature, mass, volume, humidity, pressure, Handheld Measuring Instruments and load cells. SANAS (South African National Accreditation System) is responsible for carrying out accreditations in respect of conformity assessments mandated through the Accreditation and Conformity Assessment, Calibration and Good Laboratory Practice Act (Act 19 of 2006).

SANAS is one of the Department of Trade and Industry's (DTI) Technical infrastructure institutions. NMISA, SABS, NRCS and COT11 are the other accredited institutions.

SANAS scope of recognition currently includes:

- Product calibration (ISO/IEC 17065)
- Calibration (ISO/IEC 17025)
- Testing (ISO/IEC 17025)
- Inspection (ISO/IEC 17020)



FLOW MEASUREMENT

Flow measurement is the quantification of bulk fluid (liquids, gas or steam) movement. It is categorized into volumetric flow (in litres) for constant-density liquids, and mass flow (in kg/s).

Flow measurement technologies include:

- DP which uses an orifice plate or venturi tube to calculate fluid velocity.
- Velocity flow meters such as electromagnetic, turbine, Vortex, swirl and ultrasonic meters.
- Positive displacement such as oval gear or rotary vane meters.

- Variable area (rotameters) meters.

- Mass flow directly measures the mass of fluid making them immune to temperature, density and pressure fluctuations such as thermal gas and coriolis meters.

- Open channel meters.

Flow switches are critical safety and control devices used to detect the presence, absence or rate of flow of liquids and gases in a system. They trigger automatic responses... such as sounding an alarm or shutting down a pump.



FLOW MEASUREMENT

Technologies include:

- Paddle switch
- Thermal dispersion
- Piston
- Rotameters

Flow meters have standard output analogue signals, digital outputs, Comms ports and can totalise flow rates.

Mass flow meters can measure mass, density, concentration and brics. They can be used for Hygienic applications with various process options on offer.

Flow switches have relay and digital outputs, with varying process options being available.

Flow meters and switches can be used in both standard and Ex applications, with hygienic options on offer.

Power supplies vary from 230V AC to 24V DC depending on the clients request.



HANDHELD TEST INSTRUMENTS

Handheld test instruments are portable, battery powered devices used for field diagnostics, trouble shooting and material analysis. They allow engineers and technicians to measure electrical, physical or chemical properties without needing bulky, stationery laboratory equipment.

These test instruments can be either pen or pocket size devices and are supplied with a carrying case with accessories in most cases.

Depending on the industry, these instruments span across a variety of specialised categories and applications. Digital multimeters, insulation and earth ground meters, thermal imagers and infrared thermometers, air flow anemometers and gas detectors, water quality meters, ultrasonic thickness gauges, humidity and dew point meters, tachometers, hardness testers, hygrometers, lux meters, vibration meters, manometers, pyrometers, absolute pressure meters and turbidity meters.



HUMIDITY/DEW POINT/MOISTURE MEASUREMENT

Humidity control systems regulate airborne moisture to maintain a healthy and comfortable indoor environment (usually between 30% and 50% RH). They prevent structural damage, eliminate mould and protect sensitive equipment.

These setups can range from wholesale home HVAC integrations to highly precise industrial cleanroom solutions.

Humidity refers to the amount of water vapour—invisible water in the form of gas—present in the air. It is a crucial weather and environmental factor that dictates how “sticky, muggy” or dry the air feels, impacting everything from human comfort to weather patterns and indoor mould growth.

Relative humidity: Is the amount of water vapour currently in the air compared to the.

Maximum amount the air could possibly hold at that specific temperature. It is expressed as a percentage (viz 50%).

Since warm air can hold more moisture than cold air, a drop in temperature will cause the relative humidity (RH) to rise even if no new water is added to the air.

Absolute humidity: is the actual exact mass of water vapour in a specific volume of air regardless of the temperature. It tells you exactly how much water is physically floating in the air at any given moment.

Dew point: is the exact temperature to which air must cool to become fully saturated (meaning 100% relative humidity) and turn the water vapour into liquid droplets (condensation).



HUMIDITY/DEW POINT/MOISTURE MEASUREMENT

Humidity control in manufacturing processes maintains specific RH levels to prevent defects, stop static electricity build up and ensures product stability. Maintaining strict moisture parameters reduces waste and safeguards sensitive materials across different industries.

Prevents warping, cracking or sticking of materials viz woodworking or pharmaceutical.

Static dissipation keeps humidity above a critical threshold to stop electrostatic discharge from ruining circuit boards.

Stops mould growth and bacterial contamination in food and medical products.

Protects sensitive machinery from micro-corrosion and build up.

Ideal Industry applications: Electronics and semiconductors, tobacco, pharmaceuticals, food processing and packaging, woodworking and furniture, lithium battery production, green houses, cold storage, server rooms.

Systems used: Adiabatic humidifiers, isothermal humidifiers, industrial dehumidifiers.

To achieve high accuracy results these systems rely on automated control systems.

Sensors and hygrometers... devices that measure current moisture levels.

Digital controllers.. advanced PID controllers automate the switching of connected humidifiers, dehumidifiers and fans.



INDUSTRIAL SENSORS

Industrial sensors are specialized devices that detect physical conditions like temperature, pressure or motion and convert them into electrical signals. They function as the “eyes and ears” of automated systems, providing the real-time data required for process control, predictive maintenance and equipment safety in harsh environments.

Common types of industrial sensors:

Proximity sensors: Detect the presence of an object without physical contact. Inductive types are used for metals, while capacitive types detect non-metallic materials.

Temperature sensors: Monitor thermal properties in solids, gases and liquids.

Pressure sensors: Measure the pressure of liquids or gases.

Vibration sensors: Use accelerometers to track machinery wear and tear.

Optical sensors: Utilize light beams (like laser or LED) to count items, verify packaging or detect objects on conveyors.

Ultrasonic and level sensors: Use sound waves to measure distances of fluid levels, performing well in low visibility or transparent material applications.

When specifying an industrial sensor, it is critical to match the device with the operational environment.



INDUSTRIAL SENSORS

Key selection criteria are:

Ingress Protection: (IP Rating).. ensures the sensor can resist dust, moisture and washdowns.

Connectivity: Traditional hardwire set ups (4...20mA or discrete I/O) are increasingly replaced by smart IoT - enabled networks using I/O link.

Operating Temperature: Verifies the sensor can reliably measure targets at the necessary speed and distance.

General purpose sensors commonly used are:

Inductive sensors... determined by size, length, sensing distance, PNP, NPN, 24V DC, 230V AC, 2, 3 or 4 wire with or without integral cables.

Photoelectric sensors... determined by distance and reflector size.

Contrast sensors... determined by colour applications.

Fork sensors... determined by film thickness and speed

Laser sensors... commonly known as distance sensors determined by measuring distance

These sensors are used in almost all manufacturing processes in industry and form a vital role in counting products, differentiating colours of products, rejecting below spec products, determining flow of film material in extrusion or wrapping machines etc.

The more advanced photoelectric or laser sensors will use both transmitters and receivers for more complicated applications.



INDUSTRIAL HEATING ELEMENTS

Industrial heating elements are high performance devices that convert electrical energy into heat for applications like furnaces, liquid heating and manufacturing processes.

They are typically made of high resistivity alloys such as nichrome or kanthal, insulated with magnesium oxide and encased in protective metal or ceramic sheaths.

Reviewing detailed technical literature can help you specify the right watt density, material and voltage for your application.

- Tubular elements with incoloy, stainless steel or titanium sheaths.
- Cartridge heaters with or without built in thermocouples.
- Band heaters such as mica, nozzle and ceramic.

- Supercoils mini and maxi.

- Spiral air heaters.

- Ceramic withdrawable heaters.

- Drum heaters.

These heaters can be used for heating oil, water and air and the design is dependent on the operating temperature, wattage and voltage required for each application.

The watts/density ratio for each specific heating element is critical in determining the lifespan of the element.

Industrial heating elements are custom made and are manufactured according to customer needs and specifications.



INDUSTRIAL HEATING ELEMENTS

Heating arrays for single and three phase circuits are available with thermostat or thermocouple control systems.

Voltages can be either 230/380/400/525V AC or 24/48V DC.

Hot Rod are ceramic filled incoloy tubes contained within an outer sheath of either stainless steel, titanium or vitrosol glass. They have specific cold and hot lengths and are fitted with a PVC cap and are available in different lengths, wattages and sizes (Mini or Standard). Vitrosol sheaths are ideally suited for acid solutions, titanium are suited for both alkaline and acidic solutions, whilst stainless steel tubes are ideally suited for alkaline and neutral solutions.

In certain solutions the incoloy tubes can be coated with Halar/Teflon which are used in baths with extremely high acidic solutions reaching temperatures up to 280°C. These work together with temperature and level probes which can be made of either stainless steel or Halar coating.

Flanged immersion or duct heaters use incoloy tubular heaters which are installed into water/oil baths, chemical or in situ applications.

Ceramic infrared heaters are long wave infrared heaters used primarily in vacuum forming machines, powder coating and the agricultural industry.



INSTRUMENT ACCESSORIES

Instrumentation accessories are essential components used to install, protect and optimize process control devices (such as pressure gauges, transmitters and sensors).

They ensure system integrity, accurate readings and safe operations across demanding industrial environments.

Common types include:

Compression fittings: Double or single ferrule designs used to create leak free seals on tubing (brass or stainless steel).

Connectors and adaptors: Threaded and tube-male/female connectors for seamlessly integrating instruments into existing pipelines (metric and non-metric).

Syphons and gauge cocks: Coils and pigtails used to protect pressure instruments from high temperature process fluids or steam.

Snubbers and overpressure protectors: Devices designed to dampen pressure spikes, surges and pulsations thereby extending instrument lifespan.

Mounting accessories: Brackets, wall mounts and DIN rail enclosures for fixing displays and transmitters to control panel.

Diaphragm seals and thermowells: Accessories that isolate sensitive gauges and thermometers from corrosive, viscous or high velocity media (hygienic, pulp and paper, capillary etc).

Valves and manifolds: Needle valves, check valves and manifolds used to isolate, vent or calibrate instruments.

Flanges: Weld neck, slip-on, threaded, socket weld or blind.



INSTRUMENT ACCESSORIES

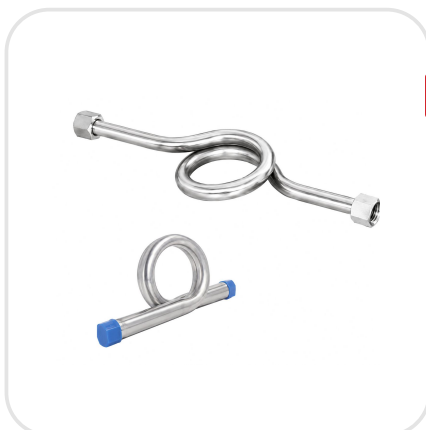
Orifice plates: A simple cost effective disc with a precisely sized hole, inserted into a pipe to measure fluid flow (concentric, eccentric and segmental).

Instrument accessories also include a wide range thermocouple plugs and sockets (standard and mini), compensating cables and instrumentation cable.

Solid State Relays (SSR's) are widely used in switching circuits where controllers typically use PID control with fast pulsing outputs for accurate processes. These devices are mounted onto heatsinks to dissipate heat transfer as they switch incredibly fast and carry heavy electrical loads.

They can be used for pulsed 3...32V DC or 85...480V AC inputs switching 85...500V AC output voltages. Current ratings can vary from 25A to 150A with either single or 3 phase units being on offer.

Din Rail power supplies with VDC inputs and varying VAC outputs with differing current ratings are available. They generally have isolated and very stable output voltages which are ideally suited for sensitive electronic controllers, indicators and other process devices.



LEVEL MEASUREMENT

Level controllers and indicators for both general purpose, ATEX and IS conditions can be supplied. These devices are fully programmable and thus tank linearization to measure level and volume are possible. Fittings to mount level devices include: reducer bushings (thread x thread), reducer bushings (socket x thread) and flange (ANSI x thread) tank adaptors.

The Webcal software is a PC utility program that enables users to easily configure and test compatible Flowline level sensors to their measurement and control requirements. The app is free and you merely connect your sensor onto the fob USB adaptor.

Various process connections such as flanges, threaded fittings, sockets, brackets and adaptors are on offer. Output signals are analogue and digital with HART and Bluetooth comms used for programming the transmitters being available.

In point level detection, a point level switch detects when a certain level is reached. Such a device is used when it is not necessary to measure every possible intermediate level. A switching command starts or stops filling equipment such as pumps or conveyors. Outputs are relay or digital signals which can be integrated into a process control system.

Level switches include:

- Buoyancy
- Capacitive
- Float
- Magneto-restrictive
- Optic
- Ultrasonic
- Vibration tuning forks



LEVEL MEASUREMENT

A combination of various fittings, flanges, sockets and adaptors are available. A complete range of controllers, indicators and programmers are on offer.

By incorporating pressure measurement one can determine levels in tanks. This is achieved by using the following principles;

Hydrostatic pressure measurement.

Differential pressure measurement.

With the help of pressure measurement the measured medium deflects the diaphragm on a pressure sensor which converts it into an electronic signal. This is achieved by fitting a chemical seal onto the pressure sensor thereby avoiding damage to the sensor and extending the life span of the pressure transmitter.

Various types of chemical seals can be used depending on the solution in the tank viz: Stainless steel, titanium, hastelloy C, ceramic or halar coated.

Magneto-restrictive indicators consist of a bypass which is mounted as a communicating tube on the side of the vessel. The float used in the bypass with integrated permanent magnet system transmits the liquid level contactless to the magnetic display mounted on the outside of the vessel. Thus the level is displayed on the magnetic indicator/flaps without external energy and can be seen from a distance. Alarms and analogue output signals are optional.



LIMIT SWITCHES

A limit switch sensor is an electromechanical device that detects the physical presence, position or end of travel of a moving object. When a machine part or object contacts its actuator, the switch opens or closes an electrical circuit, sending a signal to a controller to halt or redirect motion.

The switch features a physical actuator (such as a roller, lever, wobble, plunger or whisker) that gets physically pushed or displaced by the target. Machine safety limit switches are available as EX, ATEX or IS with protection ratings of IP67 depending on the temperature ranges.

Load current ratings vary from 1...20 Amps depending on the size of the limit switch. Switching circuit combinations vary according to the number of N/O or N/C actions as deemed necessary with either snap action or slow action modes available.

Housings can be either glass filled polyester, zinc die cast, aluminium, stainless steel, ABS resin or high strength thermoplastic with either silver or gold plated contacts.

Typical applications are: machine tools, industrial conveyors, safety interlocks, 3D printers, cranes and forklifts.



MASS MEASUREMENT

Mass is the fundamental measurement of the amount of matter an object contains. Unlike weight-which changes based on gravitational pull-mass remains constant anywhere in the universe. It is officially measured in kg.

Mass is generally scaled in different sizes..

Milligrams (mg) used for tiny quantities 1000mg
Grams (g) used for light objects such as paperclips 1000g = 1 kg.

Kilograms (kg) used for every day heavier items like a bag of flour.

Metric tons (t) used for massive quantities such as weigh bridges 1000k = 1 ton.

Typical measuring instruments used to measure mass:

Weighing scales.. utilise a calibrated spring mechanism to infer mass by measuring the downward force exerted by gravity.

Mechanical balances... include beam balances and analytical balances.

Digital load cells... used in modern scales which converts the physical downward pressure into a readable electronic reading (normally in mv).

Coriolis mass flow meter... using the Coriolis

algorithm the meter reads mass of fluids and gases.

A load cell is a specialized transducer that converts mechanical force or weight into a measurable electrical signal. By measuring tension, compression, shear or torque they are the vital sensors powering everything from industrial platform scales, weigh bridges and hoppers to medical devices and automotive testing.

Common types of load cells

Strain gauge load cells.... using the Wheatstone bridge circuit. When the metal flexes the gauges experience a tiny change in electrical resistance translating to a highly precise weight reading.

Hydraulic load cells.... These use a piston and specialised fluid (oil). As weight is applied the fluid pressure increases and is read by a pressure sensor.

Pneumatic load cells... They use air pressure to counterbalance the load.

Capacitive load cells... these measure the change in electrical capacitance between two parallel plates as the gap between them compresses under an applied load.



MECHANICAL COUPLINGS

A mechanical coupling is a component used to connect two rotating shafts to transmit power and torque while compensating for imperfections like misalignment. Couplings protect machinery from shock, vibration and overload by absorbing impacts and reducing wear on drive systems.

Metal bellow couplings are available with radial setscrews, clamping hubs, split hubs, expanded hubs, inner conical hubs and flange hubs.

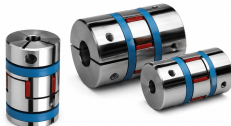
Shaft dimensions from 1...90 mm depending on the application.

Safety couplings for direct drives are a combination of the optimized torque limiting systems and a coupling element which can compensate for misalignment between the driven and drive shaft.

A wide range of metal bellows or servo inserts (spider elements) are available. For safety and overload protection of indirect drives a range of torque limiters with ball bearings and/or bush bearings are offered.

Servo insert couplings with set screw, collect clamp, split hubs, conical hubs and expanding hubs together with spider elements ensures correct stiffness, damping and torque transmission are applied.

Locking devices for self-centering and high torque 840...36000 Nm line shafts and rigid shaft couplings complete the range.



PRESSURE MEASUREMENT

Pressure measurement quantifies the force exerted by a fluid (liquid or gas) on a surface per unit area. It is a critical parameter for safety, performance and monitoring across multiple domains, ranging from industrial manufacturing, to automotive.

- Gauge Pressure measures pressure relative to the surrounding atmospheric pressure.
- Absolute Pressure measures the pressure relative to a complete vacuum.

- Differential Pressure measures the difference between two separate pressure points.

Measurement principles include mechanical gauges (bourdon tube), electronic sensors (piezoelectric, capacitive) manometers (fluid columns) and submersible sensors.

Measurement can be in PSI, Bar or kPa depending on the application with vacuum measurement being manufactured on request.



PRESSURE MEASUREMENT

The pressure gauges and transmitters can be fitted with a host of various chemical seals extending the life span of the devices which might be subject to hazardous chemicals or solutions.

Pressure gauges can be analogue or digital, dial sizes (40, 63, 100, 200, 400 mm), bottom, back or side entry with many process connections being optional. Relay outputs are available on request.

Pressure transmitters can be with or without displays, varying process and electrical connections and output signals from analog to digital.

The devices can be standard or Ex, depending on the applications.

Diaphragm seals (also known as chemical seals) can be tri-clamps, dairy, pulp paper, midi, mini or button flanged.

Typical applications include: Air conditioning, refrigeration, automotive, engineering machinery, food and beverage, filters, sealed chambers and water treatment.



PROGRAMMABLE COUNTERS

Counters in industrial automation are control devices or software instructions used to track occurrences of events such as parts passing a sensor or machine cycles. They count discrete electrical pulses and activate external circuits or outputs when a predefined preset threshold is reached.

Types of counters:

Count-Up counters (CTU): Increase the accumulated count by 1 for every signal transition (usually from OFF to ON). Often used to count finished products moving down a conveyor.

Count-Down counters (CTD): Decrease the accumulated count by 1 from a specified preset value. Useful for tracking remaining inventory or counting down parts in a batch.

UP-Down counters (CTUD): Combine both functions to track changes in opposite directions. Ideal for monitoring warehouse stock levels or tracking the number of people in a restricted area.

Common industrial applications: Batch control, quality control and predictive maintenance.

Standalone electronic counters: Physical panel mount hardware wired directly to sensors (photoelectric or limit switches).

PLC Counters: Software based counters programmed directly into PLCs.



PROGRAMMABLE LOGIC CONTROLLERS (PLC'S)

A Programmable Logic Controller is a ruggedized industrial computer to automate manufacturing processes, machinery and assembly lines. It continuously monitors sensor inputs, executes custom logic in real time and commands output devices (such as motors and valves) to operate equipment efficiently and safely.

A PLCs operation revolves around a continuous high speed called a "scan" and can be broken down into 3 primary stages:

Input scanning: The controller checks the state of all connected physical inputs (viz, limit switches, push buttons, temperature sensors etc).

Program execution: The CPU processes these inputs based on the stored logic.

Output scanning: The controller triggers or adjusts the corresponding physical outputs (viz, turning on a relay, starting a motor, opening a valve).

A standard PLC setup consists of several distinct hardware elements.

Power supply: Converts standard AC voltage into a 24 V DC supply required for the processor and modules.

Central Processing Unit (CPU): the brain of the PLC that contains the microprocessor operating system and memory to execute the code.

I/O modules: The physical interfaces that translate real-world electrical signals into digital data the CPU can understand. Inputs and outputs can be digital or analogue.



PROGRAMMABLE LOGIC CONTROLLERS (PLC'S)

The core lineup for Siemens PLCs includes the compact S7-1200 for basic to mid-range tasks, the higher performance S7-1500 for complex machines and the LOGO for small scale projects. All devices are programmed using the TIA (Totally Integrated) Portal software. The S7-1500 V is a fully virtual PLC designed for hardware - independent flexibility and efficient cloud based process control. Step 7 is the programme imbedded within the TIA Portal, utilized to configure, program and maintain your automation networks using languages such as ladder logic (LAD) and Function Block Diagrams (FBD).

Delta PLCs series include the compact DVP and modular AS range and are programmed using the DIA Designer software.

The DVP is a cost effective, high speed controller featuring abundant instructions and support for multiple communication protocols. The AS Series is a compact modular highly efficient performance PLC featuring a 32 bit SoC CPU expandable up to 32 modules and suited for multi-axis positioning and complex control. The AX Series is built for high speed motion and EtherCAT, utilizing industry standard CODESYS platforms. Delta PLCs primarily use IEC 61131-3 standard programming, meaning they support standard Ladder Logic, Function Block and Sequential Function Charts.



PROGRAMMABLE TIMERS

A digital programmable timer automates electrical devices by turning them on and off based on exact schedules. Ideal for appliances such as geysers and pool pumps these timers reduce energy waste and usually feature back up batteries to save your settings during power outages.

Common Types:

Din Rail Mount: Hardwired into your DB board to control heavy duty high loads.

Plug in timers: Easily plugs directly into a standard wall socket to control lamps, heaters and the like.

Panel mount: Industrial types with many output options and used typically in manufacturing processes.

Panel mount timers are available in the standard Din sizes (48×48, 72×72, 96×96 mm), featuring functions such as;

Sequencing 12 channel timers.

Combination timers.

Time totalizing timers.

Universal programmable timers.

Resettable thumb wheel timers.

Outputs, power supply, range and inputs are fully programmable depending on the process required in the manufacturing process.



SAFETY SYSTEMS

Safety systems are structured automated controls designed to prevent hazards, minimise risks and respond to emergencies.

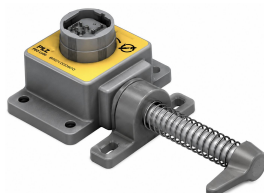
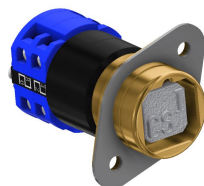
Hazardous area techniques like Intrinsic Safety (IS), Explosion Proof (EX) and Flameproof are specialised techniques required to prevent explosions in Industries where flammable atmospheres are present. Zener barriers are extensively used in these applications.

Products must be certified to International and local Standards to meet legislation to operate in these environments. Trapped key interlocks have been used as part of integrated safety systems for over 100 years. They were used to protect people during the electrification period and are used specifically in manufacturing, general industry, energy and the transportation sectors.

Products include the K range of isolation keys, bolt, claw, spring, dual and multi key interlocks. Key exchange boxes with selector switches and access control either as single, dual or multi key interlocks with or without safety switches are possible. Lock out or tagout keys are either alike or differ depending on the application.

They are available as power or mechanical isolation, controlled switching, solenoid switching, time delay interlocking, valve interlocking or motion sensing interlocks.

Safety curtains and relays are commonly used where hand operated operations are required. Typical applications include: Earthing systems, transformer access, substation equipment, loading docks, motor cages, presses and switchgear equipment which is used in all manufacturing sectors.



SAFETY SYSTEMS

Safety cycles consist of three main phases.

Isolate: The machine is turned off. Turning the power off frees the corresponding key in the lock.

Transfer: The key is physically removed from the isolated power source. Doing this mechanically locks out the power switch in the "OFF" position, ensuring it cannot be accidentally re-energized.

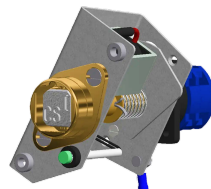
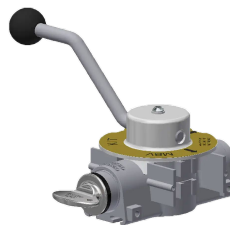
Access: The freed key is taken and inserted into a separate lock on the safety gate, door or valve. Turning the key in this lock releases the gate to open. While the gate is open, the key is trapped inside the gate lock, meaning it cannot be removed to turn the machine back on.

Key benefits include:

Eliminates human error, thus protecting workers from skipping safety protocols.

Fully mechanical: Requires no wiring, electronic switches or software making it highly reliable in harsh or explosive conditions.

Multi-key systems: For larger teams systems utilize "key exchange boxes" where multiple workers each take a personal key from the exchange box, and the machine cannot be restarted until every worker has returned their key.



SIGNAL CONDITIONING SYSTEMS

Signal conditioning is the process of manipulating a raw analogue signal into a standardized format that can be safely read and processed by a data acquisition device.

It performs several key operations to prepare raw measurements.

Linearization: Adjusts signals that have a non-linear relationship with the measured physical property (such as temperature or pressure) into a proportional straight line reading.

Excitation & conversion: Provides external energy (excitation) required to power passive sensors like RTDs and strain gauges.

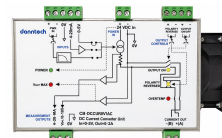
Isolation: Electrically isolates the input from the output, which helps prevent ground loops and protects delicate measurement equipment from dangerous voltage spikes.

Filtering: Removes unwanted electromagnetic noise or frequency interference.

Amplification: Increases the strength of weak signals (such as thermocouples and strain gauges) so they are easier to detect and convert.

These devices can be wall mount, panel mount or Din Rail Mount.

Optionally different electrical signals such as analogue/digital or frequency can be converted to differing electrical signals according to customer specifications.



SPEED MEASUREMENT

Speed measurement is the measure of how fast an object moves, calculated as the distance travelled divided by the time taken. They are available in a variety of options including: Zero speed, digital signals, standard or custom made designs with Ex for hazardous environments.

The range of speed sensors offers fast response and high precision tachometers for monitoring and protection. Various options include mA signals, SSRs, mechanical relays, RS485 and Ex versions. Typical applications are: Mixers/pumps, conveyors, compressors, extruders, pulp/paper mills, motor control, traction control, fans/blowers, fork lifts/cranes, heavy earth moving equipment and direction indication.

The control instruments can be either Din Rail and Panel Mount with 5-digit displays. Standard and custom made split and solid gears complement the product range.

The speed sensors which have been manufactured for more than sixty years include: Side look, hall, Bi directional and normal speed sensors.



TEMPERATURE MEASUREMENT

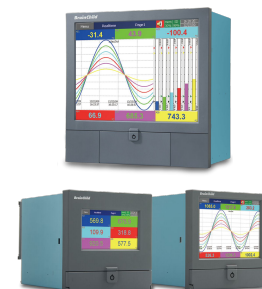
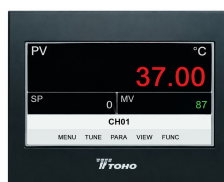
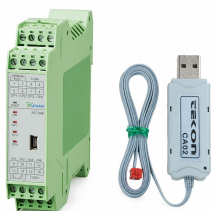
Temperature is a physical quantity that measures the degree of hotness or coldness of a substance. It is commonly measured using devices like thermometers, thermocouples and pyrometers. Measurements are typically expressed on three main scales. Celsius ($^{\circ}\text{C}$), Fahrenheit (F) and Kelvin (K). Celsius is used globally and in scientific contexts. Water freezes at 0°C and boils at 100°C at sea level pressure. Human body temperature is typically measured using medical thermometers. Air temperature is traditionally measured using electronic thermometers that detect changes in electrical resistance, or older liquid in glass thermometers.

Resistance Temperature Devices (commonly known as RTDs) are generally used for lower temperature measurement (up to 400°C) and are more accurate (0.01%). They can be used as 2, 3 or 4 wire devices depending on the accuracy required.

Thermocouples with an output mv signal work on the Seebeck principle where two dissimilar metals are fused together resulting in an output signal which relates to a thermocouple chart representing the desired temperature reading. Thermocouples can read temperatures from -90°C to $+2300^{\circ}\text{C}$. Thermocouple types are T, J, K, N, S, R, and B.

Pyrometers are primarily used as non-contact devices and can be used in temperatures up to and exceeding 2500°C . They generally use an infrared light to spot the exact temperature point which is required to be measured. Various accuracy devices are on offer depending on cost. Data logging amongst other features are optional, ranging from chart recorders to event recorders.

Thermocouples and RTDs are custom made according to specifications required by the application. There are thousands of different designs and shapes.



TEMPERATURE MEASUREMENT

The type of thermocouple determines the temperature range, length, diameter, cable length, fittings, angles, process connections and plugs all constitute the final product. In addition if aggressive gases or solutions need to be measured it is recommended to use thermowells to protect the temperature device. These thermowells or sheaths can be made of various grades of metals and/or ceramic.

Temperature controllers and indicators will either control or monitor the temperature in the process with varying output signals being available. Control outputs are usually Relay or SSR with analogue signals being used for very accurate continuous control. These devices use standard Din sizes (48×48, 72×72, 96×96 or 96×48 mm) housings. The larger the controller housing the more outputs are available, thus Comms boards and CT measurements are possible.

Temperature transmitters or Hockey Puk's

convert the mv or resistance signals to an analogue signal which is useful for high end process control and programming. These transmitters are either head mount or Din Rail mount.

Chart/Event recorders map the temperature readings in real time and can be useful for trending recordings of temperature over time. This is useful for fault finding or other data which may be required in the heating or cooling process such as autoclaves, incinerators or heating tunnels.

Temperature measurement is used in virtually all manufacturing processes and thus forms a critical role in the final products being manufactured. From plastic moulding machines to food processing to steel foundries to wood gluing to curing to furnaces to bricks and clothing it is a vital part of producing a product which is used in all sectors of society.



UNIVERSAL PROCESS CONTROLLERS

Universal process controllers are versatile, high precision industrial instruments designed to manage temperature, pressure, flow, water quality and other process variable parameters. They feature multi-channel inputs (thermocouples, mA, V), auto tuning PID control, programmable ramp-and-soak profiles, digital communication protocols such as Modbus, Profinet, Profibus, RS 485, RS23 and other protocols.

Core features and capabilities include:

Universal Inputs: These devices automatically accept a massive variety of sensors without requiring hardware changes, including thermocouples, RTD's and analogue signals.

Control outputs: They provide precise control over final elements using 4...20mA current loops, relay, SSR or digital pulses.

Advanced Tuning: Built-in auto tuning algorithms continually analyse the system to optimise PID control parameters, keeping variables precisely at the desired setpoint.

Math & Logic functions: Advanced units feature customizable logic equations, alarm management and timing routines.

These process controllers are available in standard DIN sizes (48×48, 72×72, 96×48, 96×96), with varying power supplies from DC to AC depending on customer requirements.

Intelligent Flow totalizers can be used for batching systems with output relays to control solenoid valves.



VALVE AUTOMATION

A Control valve is a power operated mechanical device used to regulate the flow of fluids (such as gas, oil, water or steam) by varying the size of the flow passage. Serving as the “final control element” in industrial automation, it directly influences process variables like pressure, temperature and liquid level.

A typical automated control valve consists of three main assemblies:

Valve body: The primary pressure boundary that contains the internal components, including the trim (plug and seal) which directly alters the fluids flow.

Actuator (single or double acting): The device that provides the mechanical force (pneumatic, hydraulic or electric) to move the valve stem and adjust the trim based on a control signal.

Positioner (mechanical or electronic): An instrument that ensures the valve is perfectly positioned to deliver the exact flow or pressure requested by the controller, minimizing friction and wear.

Control valves sit at the heart of an industrial control loop. They act dynamically like a smart doorway, linking an upstream higher-pressure source to a lower-pressure destination.

Sensors: measure a process variable and send the data to a controller.

Controller: compares the actual measurement to a desired set point.

Signal transmission: the controller sends an electrical or pneumatic signal (commonly an analogue 4...20mA signal) to the valves actuator.



VALVE AUTOMATION

Common types:

Globe valves (single seated, double seated, three way, angle or flush).

Butterfly valves.

Ball and segmented ball valves.

Diaphragm valves.

Gate valves (wedge).

Swing valves.

Knife and plug gate valves.

Typical applications include: Oil, gas, petro-chemical, food and beverage, pulp and paper, steel and chemical processing plants.

Solenoid valve is an electromechanical device that uses an electric current to control the flow of liquids and gases. It consists of an electromagnetic coil and a core (or plunger), when energised the coil creates a magnetic field.

That moves the plunger, which opens or closes the valve mechanism. Common coil voltages include: 12V DC, 24V DC, 230V AC. Body materials can be: brass, s/s or plastic.

Seal material: Viton, EPDM or PTFE depending on the temperature and application.

Common configurations:

Normally closed (N/C)

Normally open (N/O)

Direct-Acting

Pilot-Operating

Typical applications:

HVAC and Refrigeration, Plumbing and Irrigation, Pneumatic and Hydraulics.

These valves/solenoids can be supplied for EX and Hygienic applications if required.



VARIABLE SPEED DRIVES (VSD'S)

Variable Speed Drives also known as Variable Frequency Drives (VFD) is an intelligent electronic controller that manages the rotational speed and torque of an AC electric motor. It acts like an electrical dimmer switch, dynamically adjusting motor performance to meet real time demand rather than running continuously at full throttle. Modern drives use both frequency and voltage effectively using a technique called Pulse Width Modulation (PWM) instead of outputting a smooth sine wave, the drive outputs thousands of DC voltage pulses of varying widths.

A VSD sits between your electrical power source and the motor, altering the power in three main stages:

Rectifier: Converts incoming fixed frequency AC power into pulsating DC power.

DC Bus (Filter): Uses capacitors and inductors to smooth out the DC power, creating a stable and clean DC voltage.

Inverter: Uses high speed electronic switches (such as IGBTs) to convert the DC power back into AC power. By carefully dictating the voltage and frequency of this new AC waveform it accurately dictates the speed of the motor.

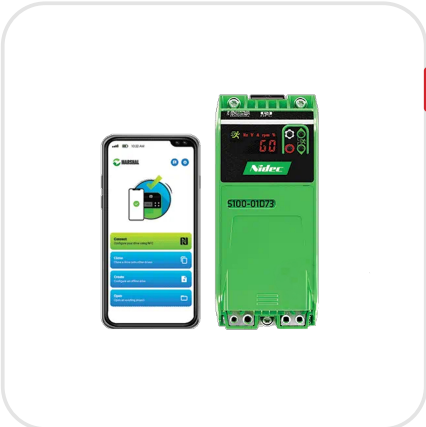
Key benefits include:

Massive energy savings.

Reduced mechanical wear.

Precise process control.

Typical applications are HVAC systems, water pumps, fans, conveyors and cranes and manufacturing processes.



VIBRATION MEASUREMENT/PNEUMATIC KNOCKERS

Vibration measurement is the process of capturing and analysing oscillating mechanical movements, most commonly used in industrial machinery condition monitoring and structural testing. It relies on sensors to convert physical vibrations into electrical signals, which are then processed by analysers to identify early faults like misalignment, imbalance or wear.

Vibration data is evaluated using three primary physical quantities.

Displacement: Measures the physical distance an object travels from its resting position. Best for monitoring low frequency vibrations.

Typical units: Millimetres (mm) or mils (thousands of an inch).

Velocity: Measures the rate at which displacement changes over time. It is the most common indicator for overall machine health in the mid-frequency range.

Typical units: mm/s or inches/s.

Acceleration: Measures the rate of change of velocity.

It is highly sensitive to high-frequency vibrations and is go-to-parameter for detecting bearing ware and gear defects.

Typical units: (gravitational force) or m/s.

Techniques used:

Accelerometers... the industry standard sensor, often using piezoelectric crystals, which generate a proportional electrical charge when subjected to vibration.

Vibration Meters/Data Loggers.... portable devices that record the vibration signals for later review or spot check maintenance tasks.

Vibration analysers... advanced diagnostic tools that process raw sensor voltages into both time-domain waveforms and frequency-domain spectrums, giving engineers a granular view of machine health.

These devices can be either 2 or 3 dimensional units so measure in the X, Y and Z axis.

Typical applications: Fans, motors, generators and hoppers.



WATER QUALITY MEASUREMENT

Water quality is measured by evaluating its physical, chemical and biological properties. Key tests include pH (acidity), Dissolved Oxygen (DO), Turbidity (clarity), Conductivity (EC), Total Dissolved Solids (TDS) and Total Suspended Solids (TSS). Measurements are typically gathered using digital multi-parameter sensors.

pH: Measures how acidic or alkaline the water is on a scale of 0...14.

Dissolved Oxygen: Essential for aquatic life to breathe.

Turbidity: Measures water clarity and amount of suspended solids.

Electrical conductivity: Evaluates the water's ability to conduct electricity, indicating the concentration of dissolved salts and minerals.

Common measurement tools:

- Portable pen and pocket multi-parameter probes which provide instant digital readouts.
- Panel or wall mount transmitters c/w field sensors and probes.
- The transmitters are single, dual or 4 channel devices with relay and analogue control outputs being on offer.
- Sensors can be either digital or analogue depending on the application.
- In addition COD, Residual chlorine, ozone and salinity meters are available.



WATER QUALITY MEASUREMENT

Water quality measurement is critical when it relates not only to effluent outflows, but also for hygienic use in all manufacturing plants. These devices not only measure but also control dosages of chemicals needed to clean and purify water quality but also ensure that the environment is kept safe and clean for human and animal habitat.

Thus measuring these values becomes a part of the entire manufacturing processes, thereby ensuring strict control to attain safety food standards.

In addition these devices offer various output options which can be linked to SCADA and PLC systems in the control room.

If continuous measurement is not possible, grab samples can be taken and tested via portable handheld test instruments, resulting in corrective action being taken by the chemical engineer.



THERMOCOUPLE EXTENSION AND COMPENSATION COLOUR CHART

Thermocouple Conductor Combination Type	Extension Cable	Compensation Cable	International Colour Code to IEC 584-3, 1989 BS 4937 Part 30, 1993	International Colour Code to IEC 584-3, 1989 BS 4937 Part 30, 1993	British to BS 1843 	American to ANSI/MC96.1 	German to DIN 43714 	French to NFC 4224 	Japanese to JIS C 1610-1981 	Conductor Combinations		Approximate Working Temperature Range of Measuring Junction		Notes
										+LEG (positive)	-LEG (negative)	Continuous	Short Term	
K	KX									NICKEL-CHROMIUM Also known as: Chrome	NICKEL-ALUMINIUM (MAGNETIC) Also known as: Ni-Al, Alume	0°C to +1100°C	180°C to +1350°C	Most suited to oxidising atmospheres. It has a wide temperature range and is the most commonly used.
		KCA												
		KCA												
T	TX									COPPER	COPPER-NICKEL Also known as: Constantan, Advance, Cupron.	185°C to +300°C	-250°C to +400°C	Excellent for low temperature and cryogenic applications. Good for when moisture may be present.
J	JX									IRON (MAGNETIC) Also known as: Fe	COPPER-NICKEL Also known as: Nickel-Copper Constantan, Advance, Cupron.	+20°C to +700°C	-180°C to +750°C	Commonly used in the plastic moulding industry. Used in reducing atmospheres as an unprotected thermocouple sensor. NB, Iron oxidises (rusts) at low and at high temperatures.
	NX									NICKEL-CHROMIUM-SILICON Also known as: Nicrosil	NICKEL-CHROMIUM-MAGNESIUM Also known as: Nisil	0°C to +1100°C	-270°C to +1300°C	Very stable output at high temperatures that can be used up to 1300°C. Good oxidation resistance. Type N stands up to temperature cycling extremely well.
N	NC													
E	EX									NICKEL-CHROMIUM Also known as: Chrome, Topical Chromium, Nickel	COPPER-NICKEL Also known as: Nickel-Copper Constantan, Advance, Cupron.	0°C to +800°C	-40°C to +900°C	Has the highest EMF output change per °C. Suitable for use in a vacuum or mildly oxidising atmosphere as an unprotected thermocouple sensor.
		RCA									PLATINUM-13% RHODIUM	PLATINUM	0°C to +1600°C	-50°C to +1700°C
R	RCB													
		SCA									PLATINUM-10% RHODIUM	PLATINUM	0°C to +1550°C	-50°C to +1750°C
S	SCB													
B										PLATINUM-30% RHODIUM	PLATINUM-6% RHODIUM	+100°C to +1600°C	+100°C to +1620°C	Type B has similar characteristics to Types R & S but is not as popular. Generally used in the glass industry.

THERMOCOUPLE CONNECTOR SELECTION GUIDE



All thermocouple connectors use true thermocouple alloys for optimum accuracy, Except for Type R, S & B which use compensating alloys.

Thermocouple Pins

Type	'+' Positive Pin	'-' Negative Pin
J	Iron	Copper Nickel
K	Nickel Chromium	Nickel Alloy
T	Copper	Copper Nickel
E	Nickel Chromium	Copper Nickel
N	Nickel / Chromium / Silicon	Nickel Silicon
R/S	Copper	Copper Alloy
B	Copper	Copper
CU	Copper	Copper

CONVERSION TABLES

PRESSURE CONVERSION TABLE

MPa	KPa	Pa	At	Bar	kg/sq.cm	mWh	lbi/ln²	ftWh
1	10³	10⁰	10.197	10	10.197	101.97	145	334.6
10³	1	10⁰	10.2 × 10³	0.01	10.2 × 10³	0.102	0.145	0.3346
10⁶	10⁶	1	10.2 × 10³	10	10.2 × 10⁶	10.2 × 10³	14.5 × 10³	33.46 × 10³
0.098	98.066	98.066 × 10³	1	0.981	1	10	14.22	32.81
0.1	100	10³	1.020	1	1.020	10.197	14.5	33.46
0.098	98.066	98.066 × 10³	1	0.981	1	10	14.22	32.81
9.807 × 10³	9.807	9.807 × 10³	0.1	0.098	0.1	1	1.422	3.281
6.895 × 10³	6.895	6.895 × 10³	0.070	0.069	0.070	0.703	1	2.307
2.988 × 10³	2.988	2.988 × 10³	0.030	0.030	0.030	0.305	0.434	1

SI UNITS AND CONVERSION FACTORS

Thermodynamics

Absolute temperature Kelvin (K)				K			Multiples & submultiples not used
Celcius temperature				°C			O°C = l273, 15K Temperature interval 1°C = 1K
Quantity of heat, joule (J)			kJ	J	mJ		
Heat flow rate, watt (W)			kW	W			
Thermal radiation densitiy, heat flow density (W m ⁻²)		MW m-2	KW m ⁻²	W m ⁻²			
Specific heat (J (kg) ⁻¹)			$\frac{\text{kJ}}{\text{kgK}}$	$\frac{\text{kJ}}{\text{kgK}}$			J (kg °C) ⁻¹
Latent heat (J (kg) ⁻¹)		MJ kg-1	J kg ⁻¹				
Coefficient of expansion (1 K ¹)				1 K ¹			Generally used with power - of - ten multiplier 1/°C = 1K ⁻¹
Thermal conductivity W (m lQ ⁻¹)			kWmK ⁻¹	WmK ⁻¹			W (m°C) ⁻¹
Heat transfer coefficient ((W m³ K) ⁻¹)			$\frac{\text{kW}}{\text{m}^2\text{K}}$	$\frac{\text{W}}{\text{m}^2\text{K}}$			W (m°C) ⁻¹
Gas constant (J (kg K) ⁻¹)				$\frac{\text{J}}{\text{KgK}}$			J (kg°C) ⁻¹
Calorimetric value (J kg ⁻¹)		$\frac{\text{Mj}}{\text{kg}}$	$\frac{\text{kj}}{\text{kg}}$				
Specific Impulse (Ns kg ⁻¹)				$\frac{\text{Ns}}{\text{kg}}$			1 NS kg ⁻¹ = 1 m s ⁻¹

MULTIPLES AND SUBMULTIPLES

The prefixes are used to form names and symbols of decimal multiples and submultiples of SI units.

Factor	Prefix	Symbol		Factor	Prefix	Symbol
10 ¹⁸	exe	E		10 ⁻¹	deci	d
10 ¹⁵	peta	P		10 ⁻²	centi	c
10 ¹²	tera	T		10 ⁻³	milli	m
10 ⁹	giga	G		10 ⁻⁶	micro	μ
10 ⁶	mega	M		10 ⁻⁹	nano	n
10 ³	kilo	k		10 ⁻¹²	pico	p
10 ²	hecto	h		10 ⁻¹⁵	femto	f
10	deca	da		10 ⁻¹⁸	atto	a

BASE SI UNITS

Quality	Name of base SI Unit	Symbol
Length	metre	m
Mass	kilogram	kg
Electric current	ampere	A
Time	second	s
Thermodynamic temperature	kelvin*	K
Luminous intensity	candela	cd
Amount of substance	mole	mol

***Note:** Temperature intervals kelvin and degree celsius are identical. A temperature expressed in degree celcius (°C) is equal to the temperature expressed in kelvin (K) less 273.15.

SUPPLEMENTARY SI UNITS

Quality	Name of base SI Unit	Symbol
Plain angle	radian	rad
Solid angle	steradian	sr

***Note:** Plane angle is commonly expressed in degrees 1° = $\frac{\text{rad}}{180}$ subdivided into minutes (') and seconds (") where required.

ALUMINIUM ALLOY CONDUCTORS (AAAC)

As per DIN Specification - DIN 48201 - Part 6 - 1981

Designation (nominal area) mm ²	Area mm ²	Number of Wires	Diam of wire mm	Overall diam mm	Breaking load kN	*DC Resistance at 20°C Ohm/ km	Weight kg/ km
16	15.89	7	1.70	5.1	4.44	2.090	43
25	24.25	7	2.10	6.3	6.77	1.370	66
35	34.36	7	2.50	7.5	9.60	0.9666	94
50	49.48	7	3.00	9.0	13.82	0.6712	135
50	48.35	19	1.80	9.0	13.50	0.6903	133
70	65.81	1919	2.10	10.5	18.38	0.5071	181
95	93.27	19	2.50	12.5	26.05	0.3578	256
120	116.99	37	2.80	14.0	23.66	0.2853	322
150	147.11	37	2.25	15.8	41.09	0.2274	406
185	181.62	61	2.50	17.5	50.73	0.1842	500
240	242.54	61	2.25	20.3	67.74	0.1382	670
300	299.43	61	2.50	22.5	83.63	0.1120	827
400	400.14	61	2.89	26.0	111.76	0.08378	1104
500	499.83	61	3.23	29.1	139.60	0.06707	1379
325	656.20	91	2.93	32.6	174.90	0.05365	1732
800	802.09	91	3.35	36.9	224.02	0.04189	2218
1000	999.70	91	3.74	41.1	279.22	0.03361	2767

FLANGE DRILLING TABLES

Valve size in inches and mm	BS 10 Table "D"					BS 10 Table "E"					BS 10 Table "F"					BS 10 Table "H"				
	No. of Holes	Hole Dia.	P.C.D.	Flange O.D.	RF Dia.	No. of Holes	Hole Dia.	P.C.D.	Flange O.D.	RF Dia.	No. of Holes	Hole Dia.	P.C.D.	Flange O.D.	RF Dia.	No. of Holes	Hole Dia.	P.C.D.	Flange O.D.	RF Dia.
1/2" 15	4	14	67	95	-	4	14	67	95	-	4	14	67	95	-	4	17	83	114	57
3/4" 20	4	14	73	102	-	4	14	73	102	-	4	14	73	102	-	4	17	83	114	57
1" 25	4	14	83	114	-	4	14	83	114	-	4	17	87	121	-	4	17	87	121	64
1 1/4" 32	4	14	87	121	-	4	14	87	121	-	4	17	98	133	-	4	17	98	133	76
1 1/2" 40	4	14	98	133	-	4	14	98	133	-	4	17	105	140	-	4	17	105	140	83
2" 50	4	17	114	152	-	4	17	114	152	-	4	17	127	165	-	4	17	127	165	102
2 1/2" 65	4	17	127	165	-	4	17	127	165	-	8	17	146	184	-	8	17	146	184	114
3" 80	4	17	146	184	-	4	17	146	184	-	8	17	165	203	-	8	17	165	203	127
4" 100	4	17	178	216	-	8	17	178	216	-	8	17	191	229	-	8	17	191	229	152
5" 125	8	17	210	254	-	8	17	210	254	-	8	22	235	279	-	8	22	235	279	178
6" 150	8	17	235	279	-	8	22	235	279	-	12	22	260	305	-	12	22	260	305	210
8" 200	8	17	292	337	-	8	22	292	337	-	12	22	324	368	-	12	22	324	368	260
10" 250	8	22	356	406	-	12	22	356	406	-	12	25	381	432	-	12	25	381	432	311
12" 300	12	22	406	457	-	12	25	406	457	-	16	25	438	489	-	16	25	438	489	362
14" 350	12	25	470	527	-	12	25	470	527	-	16	29	495	552	-	16	29	495	552	419
16" 400	12	25	521	578	-	12	25	521	578	-	20	29	552	610	-	20	29	552	610	483
18" 450	12	25	584	641	-	16	25	584	641	-	20	32	610	673	-	20	32	610	673	533
20" 500	16	25	642	705	-	16	25	642	705	-	24	32	673	737	-	24	32	673	737	597
24" 600	16	29	756	826	-	16	32	756	826	-	24	35	781	851	-	24	35	781	851	699

Valve size in inches and mm	BS 4505 Table 10					BS 4505 Table 16					BS 4505 Table 25					BS 4505 Table 40				
	No. of Holes	Hole Dia.	P.C.D.	Flange O.D.	RF Dia.	No. of Holes	Hole Dia.	P.C.D.	Flange O.D.	RF Dia.	No. of Holes	Hole Dia.	P.C.D.	Flange O.D.	RF Dia.	No. of Holes	Hole Dia.	P.C.D.	Flange O.D.	RF Dia.
1/2" 15	4	14	65	95	45	4	14	65	95	45	4	14	65	95	45	4	14	65	95	45
3/4" 20	4	14	75	105	58	4	14	75	105	58	4	14	75	105	58	4	14	75	105	58
1" 25	4	14	85	115	68	4	14	85	115	68	4	14	85	115	68	4	14	85	115	68
1 1/4" 32	4	18	100	140	78	4	18	100	140	78	4	18	100	140	78	4	18	100	140	78
1 1/2" 40	4	18	110	150	88	4	18	110	150	88	4	18	110	150	88	4	18	110	150	88
2" 50	4	18	125	165	102	4	18	125	165	102	4	18	125	165	102	4	18	125	165	102
2 1/2" 65	4	18	145	185	122	4	18	145	185	122	8	18	145	185	122	8	18	145	185	122
3" 80	8	18	160	200	138	8	18	160	200	138	8	18	160	200	138	8	18	160	200	138
4" 100	8	18	180	220	158	8	18	180	220	158	8	22	190	235	162	8	22	190	235	162
5" 125	8	18	210	250	188	8	18	210	250	188	8	26	220	270	188	8	26	220	270	188
6" 150	8	22	240	285	212	8	22	240	285	212	8	26	250	300	218	8	26	250	300	218
8" 200	8	22	295	340	268	12	22	295	340	268	12	26	310	360	278	12	30	320	375	285
10" 250	12	22	350	395	320	12	26	355	405	320	12	30	370	425	335	12	33	385	450	345
12" 300	12	22	400	445	370	12	26	410	460	378	16	30	430	485	395	16	33	450	515	410
14" 350	16	22	460	505	430	16	26	470	520	438	16	33	490	555	450	16	36	510	580	465
16" 400	16	26	515	565	482	16	30	525	580	490	16	36	550	620	505	16	39	585	660	535
18" 450	20	26	585	615	532	20	30	585	640	550	20	36	600	670	555	20	39	610	685	560
20" 500	20	26	620	670	585	20	33	650	715	610	20	36	660	730	615	20	42	670	755	615
24" 600	20	30	725	780	685	20	36	770	840	725	20	39	770	845	720	20	48	795	890	735

Valve size in inches and mm	ANSI 150					ANSI 300					ANSI 600					ANSI 900 / 1 500				
	No. of Holes	Hole Dia.	P.C.D.	Flange O.D.	RF Dia.	No. of Holes	Hole Dia.	P.C.D.	Flange O.D.	RF Dia.	No. of Holes	Hole Dia.	P.C.D.	Flange O.D.	RF Dia.	No. of Holes	Hole Dia.	P.C.D.	Flange O.D.	RF Dia.
1/2" 15	4	16	60	89	35	4	16	67	95	35	4	16	67	95	35	4	22	83	121	35
3/4" 20	4	16	70	98	43	4	19	83	117	43	4	19	83	117	43	4	22	89	130	43
1" 25	4	16	79	108	51	4	19	89	124	51	4	19	89	124	51	4	25	102	149	51
1 1/4" 32	4	16	89	117	64	4	19	98	133	64	4	19	98	133	64	4	25	111	159	64
1 1/2" 40	4	16	98	127	73	4	22	114	156	73	4	22	114	156	73	4	29	124	178	73
2" 50	4	19	121	152	92	8	19	127	165	92	8	19	127	165	92	8	25	165	216	92
2 1/2" 65	4	19	140	178	105	8	22	149	191	105	8	22	149	191	105	8	29	191	244	105
3" 80	4	19	152	191	127	8	22	168	210	127	8	22	168	210	127	-	-	-	-	-
4" 100	8	19	191	229	157	8	22	200	254	157	8	25	216	273	157	-	-	-	-	-
5" 125	8	22	216	254	186	8	22	235	279	186	8	29	267	330	186	-	-	-	-	-
6" 150	8	22	241	279	216	12	22	270	318	216	12	29	292	356	216	-	-	-	-	-
8" 200	8	22	298	343	270	12	25	330	381	270	12	32	349	419	270	-	-	-	-	-
10" 250	12	25	362	406	324	16	29	387	445	324	16	35	432	508	324	-	-	-	-	-
12" 300	12	25	432	483	381	16	32	451	521	381	20	35	489	559	381	-	-	-	-	-
14" 350	14	29	476	533	413	20	32	514	584	413	20	38	527	603	413	-	-	-	-	-
16" 400	16	29	540	597	470	20	35	571	648	470	20	41	603	686	470	-	-	-	-	-
18" 450	16	32	578	635	533	24	35	629	711	533	20	44	654	743	533	-	-	-	-	-
20" 500	20	32	635	699	584	24	35	686	775	584	24	44	724	813	584	-	-	-	-	-
24" 600	20	35	749	813	692	24	41	812	914	692	24	51	838	940	692	-	-	-	-	-

Adjacent “**TABLES**” with colour shading in the same row indicates identical dimensions.

IP RATING REFERENCE CHART

IP Rating	First Digit - SOLIDS	Second Digit - LIQUIDS
IP00	Not protected from solids.	Not protected from liquids.
IP01	Not protected from solids.	Protected from condensation.
IP02	Not protected from solids.	Protected from water spray less than 15 ° from vertical.
IP03	Not protected from solids.	Protected from water spray less than 60 ° from vertical.
IP04	Not protected from solids.	Protected from water spray from any direction.
IP05	Not protected from solids.	Protected from low pressure water jets from any direction.
IP06	Not protected from solids.	Protected from high pressure water jets from any direction.
IP07	Not protected from solids.	Protected from immersion between 15 cm and 1 m in depth.
IP08	Not protected from solids.	Protected from long term immersion up to a specified pressure.
IP10	Protected from touch by hands greater than 50 mm.	Not protected from liquids.
IP11	Protected from touch by hands greater than 50 mm.	Protected from condensation.
IP12	Protected from touch by hands greater than 50 mm.	Protected from water spray less than 15 ° from vertical.
IP13	Protected from touch by hands greater than 50 mm.	Protected from water spray less than 60 ° from vertical.
IP14	Protected from touch by hands greater than 50 mm.	Protected from water spray from any direction.
IP15	Protected from touch by hands greater than 50 mm.	Protected from low pressure water jets from any direction.
IP16	Protected from touch by hands greater than 50 mm.	Protected from high pressure water jets from any direction.
IP17	Protected from touch by hands greater than 50 mm.	Protected from immersion between 15 cm and 1 m in depth.
IP18	Protected from touch by hands greater than 50 mm.	Protected from long term immersion up to a specified pressure.
IP20	Protected from touch by fingers and objects greater than 12 mm.	Not protected from liquids.
IP21	Protected from touch by fingers and objects greater than 12 mm.	Protected from condensation.
IP22	Protected from touch by fingers and objects greater than 12 mm.	Protected from water spray less than 15 ° from vertical.
IP23	Protected from touch by fingers and objects greater than 12 mm.	Protected from water spray less than 60 ° from vertical.
IP24	Protected from touch by fingers and objects greater than 12 mm.	Protected from water spray from any direction.
IP25	Protected from touch by fingers and objects greater than 12 mm.	Protected from low pressure water jets from any direction.
IP26	Protected from touch by fingers and objects greater than 12 mm.	Protected from high pressure water jets from any direction.
IP27	Protected from touch by fingers and objects greater than 12 mm.	Protected from immersion between 15 cm and 1 m in depth.
IP28	Protected from touch by fingers and objects greater than 12 mm.	Protected from long term immersion up to a specified pressure.
IP30	Protected from tools and wires greater than 2.5 mm.	Not protected from liquids.
IP31	Protected from tools and wires greater than 2.5 mm.	Protected from condensation.
IP32	Protected from tools and wires greater than 2.5 mm.	Protected from water spray less than 15 ° from vertical.
IP33	Protected from tools and wires greater than 2.5 mm.	Protected from water spray less than 60 ° from vertical.
IP34	Protected from tools and wires greater than 2.5 mm.	Protected from water spray from any direction.
IP35	Protected from tools and wires greater than 2.5 mm.	Protected from low pressure water jets from any direction.
IP36	Protected from tools and wires greater than 2.5 mm.	Protected from high pressure water jets from any direction.
IP37	Protected from tools and wires greater than 2.5 mm.	Protected from immersion between 15 cm and 1 m in depth.
IP38	Protected from tools and wires greater than 2.5 mm.	Protected from long term immersion up to a specified pressure.
IP40	Protected from tools and small wires greater than 1 mm.	Not protected from liquids.
IP41	Protected from tools and small wires greater than 1 mm.	Protected from condensation.
IP42	Protected from tools and small wires greater than 1 mm.	Protected from water spray less than 15 ° from vertical.

IP41	Protected from tools and small wires greater than 1 mm.	Protected from condensation.
IP42	Protected from tools and small wires greater than 1 mm.	Protected from water spray less than 15° from vertical.
IP43	Protected from tools and small wires greater than 1 mm.	Protected from water spray less than 60° from vertical.
IP44	Protected from tools and small wires greater than 1 mm.	Protected from water spray from any direction.
IP45	Protected from tools and small wires greater than 1 mm.	Protected from low pressure water jets in any direction.
IP46	Protected from tools and small wires greater than 1 mm.	Protected from high pressure water jets from any direction.
IP47	Protected from tools and small wires greater than 1 mm.	Protected from immersion between 15 cm and 1 m in depth.
IP48	Protected from tools and small wires greater than 1 mm.	Protected from long term immersion up to a specified pressure.
IP50	Protected from limited dust ingress.	Not protected from liquids.
IP51	Protected from limited dust ingress.	Protected from condensation.
IP52	Protected from limited dust ingress.	Protected from water spray less than 15° from vertical.
IP53	Protected from limited dust ingress.	Protected from water spray less than 60° from vertical.
IP54	Protected from limited dust ingress.	Protected from water spray from any direction.
IP55	Protected from limited dust ingress.	Protected from low pressure water jets from any direction.
IP56	Protected from limited dust ingress.	Protected from high pressure water jets from any direction.
IP57	Protected from limited dust ingress.	Protected from immersion between 15 cm and 1 m in depth.
IP58	Protected from limited dust ingress.	Protected from long term immersion up to a specified pressure.
IP60	Protected from total dust ingress.	Not protected from liquids.
IP61	Protected from total dust ingress.	Protected from condensation.
IP62	Protected from total dust ingress.	Protected from water spray less than 15° from vertical.
IP63	Protected from total dust ingress.	Protected from water spray less than 60° from vertical.
IP64	Protected from total dust ingress.	Protected from water spray from any direction.
IP65	Protected from total dust ingress.	Protected from low pressure water jets from any direction.
IP66	Protected from total dust ingress.	Protected from high pressure water jets from any direction.
IP67	Protected from total dust ingress.	Protected from immersion between 15 cm and 1 m in depth.
IP68	Protected from total dust ingress.	Protected from long term immersion up to a specified pressure.
IP69K	Protected from total dust ingress.	Protected from steam-jet cleaning.

ELECTRICAL ENGINEERING

Electric current ampere (A)		kA	A	mA	μA	nA		
Electric charge, coulomb (C)			C	mC	μC			1 C = 1 A z 1 s
Electric potential electromotive force, volt (V)	MV	Kv	V	mV	μV			
Power (Active), watt (W)		kW	W	mW	μW			1 W = 1 V z 1 A
Apparent power (VA)	MVA	kVA	VA					
Resistance impedance reactance ohm (Ω)	M Ω	k Ω	Ω	m Ω				
Capacitance farad (F)				mF	μF	nF	pF	mF, nF not generally used
Inductance, henry (H)			H	mH				

VST SELECTION GUIDE

Application	1st Choice					2nd Choice			
	Monovalve Float	Bimetallic®	Multi-Segment	Bimetallic®	Piston Operated®	Thermodynamic	Monovalve Float	Bimetallic®	Multi-Segment
Steam Mains									
0-15 psig	✓						✓		
15-600 psig		✓							✓
to 1500 psig		✓							✓
to 2500 psig		✓							✓
to 4500 psig		✓							✓
with Superheat		✓							✓
Separators	✓							✓	
Steam Tracer									
Critical		✓							✓
Non-Critical		✓							✓
Heating Equipment									
Shell & Tube Heat Exchangers	✓							✓	
Heating Coils	✓							✓	
Unit Heaters	✓					✓			
Plate & Frame Heat Exchangers	✓							✓	
Radiators		✓							
General Process Equipment									
to 200 psig	✓								
to 600 psig		✓							
to 900 psig		✓							
to 1500 psig		✓							
Hospital Equipment									
Auto clones	✓						✓		
Sterilizers	✓						✓		
Fuel Oil Heating									
Bulk Storage Tanks		✓			✓				
Line Heaters	✓								
Tanks & Vats									
Bulk Storage Tanks		✓			✓				
Process Vats	✓								✓
Vulcanizers	✓								✓
Evaporators	✓								✓
Reboilers			✓			✓			
Rotating Cylinders	✓								
Freeze Protection		✓							

DERIVED UNITS

Quantity	Definition	Name of derived unit	Symbol	Expressed in terms of base of supplementary SI Units, or in terms of other derived units
Frequency	The unit of frequency is the frequency of a period.	hertz	Hz	$1\text{ Hz} = 1\text{ s}^{-2}$
Force	The unit of force is that force which, when applied to a body having mass of one kilogram gives it an acceleration of one metre per second.	newton	N	$1\text{ N} = 1\text{ kg m s}^{-2}$
Pressure and Stress	The unit of pressure is the pressure produced by a force of one newton applied, uniformly distributed, over an area of one square metre.	pascal	Pa	$1\text{ Pa} = 1\text{ N m}^{-2}$
Work, energy quantity of heat	The unit of energy is the work done when the point of application of a force of one newton is displaced through a distance of one metre in the direction of the force.	joule	J	$1\text{ J} = 1\text{ N m}^{-1}$
Power	The unit of power is equal to one joule per second Power is the rate of which work is done.	watt	W	$1\text{ J} = 1\text{ J s}^{-1}$
Electric conductance	The inversion of electrical resistance	siemens	S	$1\text{ S} = 1\text{ A V}^{-1}$
Magnetic flux, flux of magnetic induction	The unit of magnetic flux is the flux which, linking a circuit of one turn, produced in it an electromotive force of one volt as it is reduced to zero at a uniform rate in one second.	weber	Wb	$1\text{ Wb} = 1\text{ V s}$
Magnetic flux, flux of magnetic induction	The unit of magnetic flux density is the density of one weber of magnetic flux per square metre.	tesla	T	$1\text{ T} = 1\text{ Wb m}^{-2}$
Inductance	The unit of electrical inductance is the inductance of a closed circuit in which an electromotive force of one volt is produced when the electric current in the circuit varies uniformly at the rate of one ampere per second.	henry	H	$1\text{ H} = 1\text{ Wb A}^{-1}$
Luminous flux	The unit of luminous flux is the flux emitted within unit solid angle of one steradian by a point source having a uniform intensity of one candela.	lumen	lm	$1\text{ lm} = 1\text{ cd sr}$
Illumination	The unit of illumination is an illumination of one lumen per square metre.	lux	lx	$1\text{ lx} = 1\text{ lm m}^{-2}$
Quantity of electrical charge	The unit of electrical charge is the quantity of electricity transported in one second by a current of one ampere.	Coulomb	C	$1\text{ C} = 1\text{ A s}$
Electrical potential, potential difference, tension electromotive force	The unit of electric potential is the difference of potential between two points of a conducting wire carrying a constant current of one ampere when the power dissipated between these points is equal to one watt.	volt	V	$1\text{ V} = 1\text{ W A}^{-1}$
Electrical capacitance	The unit of electrical capacitance is the capacitance of a capacitor between the plates of which there appears a difference of potential of one volt when it is charged by a quantity of electricity equal to one coulomb.	farad	F	$1\text{ F} = 1\text{ C V}^{-1}$
Electrical resistance	The unit of electric resistance is the resistance between two points of a conductor when a constant difference of potential of one volt applied between these two points produces in this conductor a current of one ampere, this conductor not being this source of any electromotive force.	ohm	Ω	$1\text{ }\Omega = 1\text{ V A}^{-1}$

CONVERSION FACTORS: METRIC AND IMPERIAL UNITS TO SI UNITS

GEOMETRIC LENGTH

Unit	M	km	mile	yd	feet	inches	nautical mile
m	1	0.001	0.6213712×10^{-3}	1.093613	3.280839	39.370079	0.539957×10^{-3}
km	1000	1	0.6213712	1093.613	3280.839	39370.079	0.539957
mile	1609.344	1.609344	1	1760	5280	63360	0.868976
yd	0.9144	0.9144×10^{-3}	0.568182×10^{-3}	1	3	36	0.493736×10^{-3}
ft	0.3048	0.3046×10^{-3}	0.189394×10^{-3}	0.333333	1	12	0.164579×10^{-3}
in	0.0254	0.0254×10^{-3}	15.7828×10^{-4}	0.0277778	0.083333	1	-
nautical mile	1852	1.852	1.15078	2025.373	6076.12	-	1

- This is the internation unit: 1 (int) n. mile = 0.999362 UK n. mile
- Note. The micron is now called the micrometre (µm) and = 39.3701 µ inch
- 10 Angstrom units (A) = 1 millimicron - 1×10^{-9} mm

AREA

- Square the conversion factors given in Table to obtain the desired factor

VOLUME

Unit	m³	litre	ft³	in³	UK gal
m³	1	10³	35.31467	61023.74	219.9688
litre	10^{-3}	1	0.0353147	61.02374	0.2199688
ft³	0.0283168	20.31685	1	1728	6.22837
in³	16.38706×10^{-6}	16.38706×10^{-3}	0.5787×10^{-3}	1	-
UK gal	0.0045461	4.546091	0.160544	277.419	1

- 1 UK gal = 0.0045461 USA gal
- 1 US gal = 0.832957 UK gal

MASS

Uni	kg	lb	t	UK ton	slug
kg	1	2.204623	10^{-3}	0.984207×10^{-3}	0.06852177
lb	0.453550237	1	0.0004536	0.00044643	0.03108095
t	1000	2264.623	0.96421	0.96421	-
UK ton	1016.0467	2240	1	1	-
slug	14.5635	32.17406	-	-	1

- UK ton = 2000 lb = 0.892857 UK tons = 1.12 US ton

DENSITY (MASS/VOLUME)

Unit	kg m ⁻³	g cm ⁻³	lb ft ⁻³	lb in ⁻³	lb gal ⁻³	slug ft ⁻³
kg m ⁻³	1	10 ⁻³	62.42796 x 10 ⁻³	0.036128 x 10 ⁻³	0.0100224	1.94032 x 10 ⁻³
g cm ⁻³	10	1	62.42796	0.036128	10.0224	1.94032
lb ft ⁻³	16.01846	0.01601846	1	0.0576704 x 10 ⁻³	0.160544	0.031081
lb in ⁻³	27679.9	27.6799	1728	1	277.42	53.708
lb gal ⁻³	99.7764	0.099764	6.228843	0.00360465	1	-
slug ft ⁻³	515.379	0.515379	32.17405	0.018619	-	1

- 1 g cm⁻³ = 1 kg dm⁻³ = 1kg 1⁻³ The value of the litre as defined in 1901 is 1.000028 dm¹. In 1964 the XII CGPM ruled that for practical purposes the cubic decimetre can be called the litre. The values in the above tables are based on this decision
- 1 gal = 1.20095 US gal; 1 Us gal = 0.832675 gal

FORCE

Unit	N	lbf	pdl	kgf	UK tonf
N	1	0.224809	7.233011	0.101971621	0.100361 x 10 ⁻³
lbf	4.448222	1	32.17405	0.453602	0.446429 x 10 ⁻³
pdl	0.138255	0.031081	1	0.0140961	0.01388 x 10 ⁻³
kgf	9.80655	2.204622	70.931607	1	0.984207 x 10 ⁻³
UK tonf	9964.0173	2240	72069672	1016.047	1

- The force unit lbl, kgf, tonf, all contain the standard value of the free fall acceleration die to gravity, gn = 32.17405 ft s⁻², 9.80665 m s⁻² eg the force to support 1 kg (mass) is 1 kgf = 9.80665 N
- The kgf is also known as the kilopond (kp)

PRESSURE - LOADING - STRESS

Uni	N m ⁻² (Pa)	kgf mm ²	lbf in ⁻²	lbf ft ⁻²	tonf in ⁻²	MN m ⁻² (MPa)
N m ⁻²	1	0.101972 x 10 ⁶	0.145038 x 10 ⁻³	0.0208854	64.7488 x 10 ⁻⁹	10 ⁻⁶
kgf mm ²	9.80665 x 10 ⁶	1	1422.334	204516.1	0.634971	9.80665
lbf in ⁻²	6894.761	0.70307 x 10 ⁻³	1	144	0.446429 x 10 ⁻³	6.894761 x 10 ⁻³
lbf ft ⁻²	47.8803	4.88243 x 10 ⁻⁶	6.9444 x 10 ⁻³	1	3.1002 x 10 ⁻⁶	47.8803 x 10 ⁻⁶
tonf ⁻²	15.4443 x 10 ⁶	1.57488	2240	322560	1	15.4443
MN m ⁻²	10 ⁶	0.101972	145.0377	20885.43	64.7488 x 10 ⁻³	1

- 10 MN m⁻² = 1 hectobar (h bar) = 10 MPa = 10 N nm⁻²
- pz = 1 sthene m⁻² (sn m⁻²) = 103 Pa
- 1 atm = 1.01325 bar = 760 mm Hg = 1013.25 m bar = 0.101325 MN m⁻²

FORCE PER UNIT LENGTH - SPRING RATE - BEAM LOADING

Unit	Nm ⁻¹	kgf m ⁻¹	lbf in ⁻¹	lbf ft ⁻¹	tonf in ⁻¹
Nm	1	0.101972	5.71017 x 10 ⁻³	68.5221 x 10 ⁻³	2.546263 x 10 ⁻⁶
kgf m ⁻¹	9.80665	1	55.9975 x 10 ⁻³	0.671968	24.9967 x 10 ⁻³
lbf in ⁻¹	175.127	17.565	1	12	0.446429 x 10 ⁻³
lbf ft ⁻¹	14.5939	1.48816	0.083333	1	37.2024 x 10 ⁻⁶
tonf in ⁻¹	392264	40001.9	2240	26880	1

- Nm = 10⁻³ N mm⁻¹

MOMENT - TORQUE - TORSION

Unit	Nm	N cm	ft lbf	in lbf	ozf in
Nm	1	100	0.737562	8.850745	141.61192
N cm	10^{-2}	1	7.37565×10^{-3}	88.50745×10^{-3}	1.4161192
lbf ft	1.355818	135.5818	1	12	192
lbf	0.112985	11.2985	0.833333	1	16
ozf in	0.007062	0.706155	0.00520833	0.0625	1

MOMENT OF INERTIA

Unit	kg m ²	kg mm ²	lb ft ²	slug ft ²	lb in ²
kg m ²	1	10^6	23.7304	0.737565	0.100361×10^{-3}
kg mm ²	10^{-6}	1	23.7304×10^{-6}	$.737565 \times 10^{-6}$	0.446429×10^{-3}
lb ft ²	0.04214	42140	1	0.031081	3.41718×10^{-3}
slug ft ²	1.35573	1355730	32.17405	1	4633.06
lb in ²	0.292639×10^{-3}	292.639	6.94444×10^{-3}	0.21588×10^3	1

SECOND MOMENT OF AREA

Unit	cm ⁴	ft ⁴	in ⁴	mm ⁴
cm ⁴	1	1.15862×10^{-6}	0.0240251	104
ft ⁴	863097	1	.20736	86309.7×10^3
in ⁴	41.6231	48.2253×10^{-6}	1	416.231×10^3
mm ⁴	10^{-4}	0.115862×10^{-9}	2.4025×10^{-6}	1

SPECIFIC HEAT

(mass basis; heat/mass x degree temperature)

Unit	J (kg °C) ⁻¹	kcal (kg °C) ⁻¹	Btu (lb °F) ⁻¹	ft (lbf °F) ⁻¹	kgf m (kg °C) ⁻¹
J (kg °C) ⁻¹	1	0.238846×10^{-3}	0.238846×10^{-3}	0.185863	0.101972
kcal (kg °C) ⁻¹	4186.8	1	1	778.169	426.935
Btu (lb °F) ⁻¹	4186.8	1	1	778.169	426.935
ft (lbf °F) ⁻¹	5.3803	0.00128507	0.00128507	1	3.54864
kgf m (kg °C) ⁻¹	9.80665	0.00234228	0.00234228	1.82269	2

SPECIFIC HEAT CAPACITY

Bty = British thermal units (volume basis; heat/mass x degree temperature)

Unit	J m-3 °C ⁻¹	Kcal m ⁻³ °C	Btu ft ⁻³ °F ⁻¹
J m-3 °C ⁻¹	1	0.238846×10^{-3}	0.0149107×10^{-3}
Kcal m ⁻³ °C	4186.8	1	0.062428
Btu ft ⁻³ °F ⁻¹	67066.1	16.0185	1

CALORIFIC VALUE (MASS)

(mass basis; heat/mass) (specific energy, specific latent heat)

Unit	J kg ⁻¹	Cal kg ⁻¹	Btu lb ⁻¹	Ft lbf lb ⁻¹	kgf m kg ⁻¹
J kg ⁻¹	1	0.238846 x 10 ⁻³	0.429923 x 10 ⁻³	0.334558	0.101972
kcal kg ⁻¹	4186.8	1	1.8	14000.7	426935
Btu lb ⁻¹	2326	0.555556	1	778.169	237.186
ft lbf lb ⁻¹	2.98907	0.713926 x 10 ⁻³	1.28507 x 10 ⁻³	1	0.3048
kgf m kg ⁻¹	9.806665	2.34228 x 10 ⁻³	4.2161 x 10 ⁻³	3.28084	1

CALORIFIC VALUE (VOLUME)

(volume basis ; heat/volume)

Unit	J cm ⁻³	kcal m ⁻³	Btu ft ⁻³
J cm ⁻³	1	238.846	26.8392
kcal m ⁻³	0.004186	1	0.11237
Btu ft ⁻³	0.0372589	8.89915	1

For gases it is assumed that the values involved in conversion are measured under the same conditions of temperature and pressure.

THERMAL CONDUCTANCE

(heat/area x time x degree temperature)

Unit	cm ⁴	ft ⁴	in ⁴	mm ⁴
W m ⁻² °C ⁻¹	1	1.15862 x 10 ⁻⁶	0.0240251	104
cal m ⁻² s ⁻¹ °C ⁻¹	863097	1	.20736	86309.7 x 10 ³
Btu ft ⁻² h ⁻¹ °F ⁻¹	41.6231	48.2253 x 10 ⁻⁶	1	416.231 x 10 ³
kcal m ⁻² h ⁻¹ °C ⁻¹	10 ⁻⁴	0.115862 x 10 ⁻⁹	2.4025 x 10 ⁻⁶	1

ENERGY - WORK - QUANTITY OF HEAT

Unit	J = 1 Mn	W h	kgf m	lbf ft	cal	Btu
J	1	7.50062 x 10 ⁻³	0.101971621	0.7375621	0.238846	0.947817 x 10 ⁻³
W h	3600	1	367.09786	2655224	859.8456	3.412141
kgf m	9.80665	2.7241 x 10 ⁻³	1	7.233013	2.348279	9.294901 x 10 ⁻³
lbf ft	1.355818	3.76616 x 10 ⁻³	0.138255	1	0.323832	1.2851 x 10 ⁻³
cal	4.1868	0.001163	0.42935	3.088024	1	3.968318 x 10 ⁻³
Btu	1055.056	0.2933071	107.5858	778.16931	251.9959	1

1 pdl ft = 0.04214011 J 1 Centigrade Heat Unit (CHU) = 1.8 Btu 1 them = 105.506MJ
1 thermie = 4.1855 MJ The calorie used is the International Steam Table Calorie

EQUIVALENT MERCURY OF WATER COLUMN PRESSURES

Unit	N m ⁻² (Pa)	(torr) mm Hg	in Hg	mm H ₂ O	in H ₂ O	atm
N m ⁻²	1	7.50062 x 10 ⁻³	0.2953 x 10 ⁻³	0.101974	4.01474 x 10 ⁻³	9.86923 x 10 ⁻⁶
mm Hg	133.322	1	0.03937	13.5955	0.535255	1.31579 x 10 ⁻³
in Hg	3386.39	25.4	1	345.325	13.5955	0.033421
mm H ₂ O	9.80638	0.073554	0.002896	1	0.03937	0.096771 x 10 ⁻³
in H ₂ O	249.082	1.86827	0.073554	25.4	1	0.002458
atm	101.325 x 10 ⁻³	760	29.9213	10.3326 x 10 ⁻³	406.794	1

1 mm Hg = 1 torr Mercury column values based on t = 0 °C, p = 760 mm Hg, gn = 2.80665
m s -2 Water column values are based on t = 4 °C, p = 760 mm Hg, gn = 2.80665 m s -2
The french abbreviation for water column is CE; the German equivalent is WS For any other
values of temperature and pressure and local values of 'g' the table values will require to be
altered pn for Hg = 13595.1 kg m-3; on for water = 999.972 kg m-3

HEATING CALCULATIONS

Heating Sheet metal from 20 - 400° C in 5 minutes
Ptheor = b • l • d • p • c • ΔT/t

P	=	heating power (kW)	Data	=	
b	=	width (m)	b	=	0.8
l	=	length (m)	l	=	2.0
d	=	thickness (m)	d	=	0.02
p	=	density (kg/m3)	ΔT	=	380
c	=	Temperature increase (K)	p	=	7.8 10³
t	=	heating time	c	=	0.46
n	=	efficiency	t	=	300
m	=	mass (kg)	n	=	0.55

TYPICAL MATERIALS DATA

Unit	Density at 20 °C (10³kg/m³)	Specific Heat capacity (kJ/kgK)
Aluminium	2.7	0.90
Brass	8.4	0.38
Cast Iron	5.7 - 7.2	0.50
Copper	8.9	0.39
Iron	7.85	0.45
Steel	7.8	0.46
Tin	7.3	0.23
Zinc	7.14	0.39
Water	1.00	4.18
Paper	0.6 - 1.2	1.5 - 1.7
Asbestos	2.0	0.84
Concrete, dry	1.5 - 2.4	0.90
Glass	2.5	0.84
Refractory brick	1.8	0.75
Polyethelene	0.92 - 0.96	2.3
PVC	1.4	0.85 - 1.17

TYPICAL MATERIALS DATA

Unit	=	in³	ft³	yd³	gal (UK)	gal (US)	cm³	dl³ (l)	m³
1 in³	=	1	-	-	-	-	16.3871	0.01638	-
1 ft³	=	1728	1	0.03704	6.229	7.481	-	28.3168	0.02832
1 yd³	=	46656	27	1	168.18	201.97	-	764.555	0.76456
1 gal (UK)	=	277.42	0.16054	-	1	1.20095	4546.09	4.54609	-
1 gal (US)	=	231	0.13368	-	0.83267	1	3785.41	3.78541	-
1 cm³	=	0.06102	-	-	-	-	-1	0.001	-
1 dm³ (l)	=	61.0236	0.03531	0.00131	0.21997	0.26417	1000	10	0.001
1 m³	=	61023.6	35.315	1.30795	219.969	264.172	10⁶	1000	1

in³ = cubic inch (cu in), yd³ = cubic yard (cu yd)
ft³ = cubic foot (cu ft), gal = gallon

PRESSURE UNITS CROSS REFERENCE CHART

PSI	atms	in. H2O	mm H2O	cm H2O	oz/in2	kg/cm2	in Hg	mm Hg	cm Hg	mbar	bar	Pa	kPa	mPa
1	0.06805	27.68	703.1	70.31	16.00	0.07031	2.036	51.72	5.172	68.95	0.06895	6895	6.895	0.006895
14.70	1	406.8	10332	1033	235.1	1.033	29.92	760.0	76.00	1013	1.013	101325	101.3	0.1013
0.03613	0.002458	1	25.40	2.540	0.5780	0.002540	0.07356	1.868	0.1868	2.491	0.002491	249.1	0.2491	0.00025
0.001422	9.678E-05	0.03937	1	0.1000	0.02276	1.000E-04	0.002896	0.07355	0.007355	0.09806	9.806E-05	9.806	0.009806	0.000010
0.01422	0.000968	0.3937	10.00	1	0.2276	0.0010	0.02896	0.7356	0.07356	0.9807	0.0009807	98.07	0.09807	0.00010
0.0625	0.004253	1.730	43.94	4.394	1	0.004394	0.1273	3.232	0.3232	4.309	0.004309	430.9	0.4309	0.0004309
14.22	0.9678	393.7	10000	1000	227.6	1	28.96	735.6	73.56	980.7	0.9807	98066	98.07	0.098066
0.49115	0.03342	13.59	345.3	34.53	7.858	0.03453	1	25.40	2.540	33.86	0.03386	3386	3.386	0.003386
0.01934	0.001316	0.5352	13.60	1.360	0.3094	0.001360	0.03937	1	0.1000	1.33	0.001333	133.3	0.1333	0.0001333
0.1934	0.01316	5.352	136.0	13.60	3.094	0.01360	0.3937	10	1	13.33	0.01333	1333	1.333	0.001333
0.0145	0.0009869	0.4015	10.20	1.020	0.2321	0.001020	0.02953	0.7501	0.07501	1	0.001000	100.0	0.10000	0.0001
14.50	0.9869	401.5	10197	1020	232.1	1.020	29.53	750.1	75.01	1000	1	100000	100.0	0.1000
0.000145	9.867E-06	0.004014	0.1019	0.01019	0.002320	1.019E-05	0.0002952	0.007499	0.000750	0.01000	9.9974E-06	1	0.0009997	0.000001
0.1450	0.009869	4.015	102.0	10.20	2.321	0.01020	0.2953	7.501	0.7501	10.00	0.01000	1000	1	0.001
145.0	9.869	4014	101968	10197	2321	10.20	295.3	7500	750.0	10000	10.00	1000000	1000	1

To use this chart:

1. Find the column with the units you want to convert **from**.
2. Move down that column until you find the "1".
3. Staying in the same **row**, move horizontally to the column with the units you are converting **to**.
4. Multiply the number in that box by the amount you are changing from to get the converted value.

UNITS OF MASS

(Colloquially also called 'units of weight')

Avoirdupois - System (commercial weights in general use in the UK and US)

Unit	gr	dram	oz	lb	cwt (UK)	cwt (US)	ton (UK)	ton (US)	g	kg	t
1 gr	1	0.03657	0.00229	1/7000	-	-	-	-	0.064799	-	-
1 dram	27.344	1	0.0625	0.00391	-	-	-	-	1.77184	-	-
1 oz	437.5	16	1	0.0625	-	-	-	-	28.3495	-	-
1 lb	7000	256	16	1	0.00893	0.01	-	0.0005	453.592	0.45359	-
1 cwt (UK) ¹	-	-	-	112	1	1.12	0.05	-	-	50.8023	-
cwt (US) ²	-	-	-	100	0.8929	1	0.04464	0.05	-	45.3592	-
1 ton (UK) ³	-	-	-	2240	20	22.4	1	1.12	-	1016.05	1.01605
1 ton (US) ⁴	-	-	-	2000	17.857	20	0.8929	1	-	907.185	0.90718
1 g	15.432	0.5644	0.03527	-	-	-	-	-	1	0.001	-
1 kg	-	-	35.274	2.2046	0.01968	0.02205	-	-	1000	1	0.001
1 t	-	-	-	2204.6	19.684	22.046	0.9842	1.1023	10 ⁶	1000	1

UK = United Kingdom, US = USA,

gr = gram, oz = ounce, lb = pound, cwt = hundredweight

1 slug = 14.5939 kg = mass, accelerated at 1 ft/s² by a force of 1 lbf

1 st (stone) = 14 lb = 6.35 kg (UK only)

1 qr (quarter) = 28 lb = 12.7006 kg (UK only, seldom used)

1 quintal = 100 lb = 1 short cwt = 45.3592 kg

1 tdw (ton dead weight) = 1 long ton = 1.016 t

1 troy ounce = 33 g

The tonnage of dry cargo ships (cargo + ballast + fuel + supplies) is given in tdw.

1) also called "long cwt (cwt l)"

2) also called "shoprt cwt (cwt sh)"

3) also called "long ton (tn l)"

4) also called "short ton (tn sh)"

OTHER BRITISH AND AMERICAN UNITS OF VOLUME

Volume of ships

1 RT (register ton) = 100 ft³ = 2.832 m³, GRT (gross RT) = total shipping space, net register ton = cargo space of a ship. GTI (gross tonnage index) = total volume of ship (shell) in m³.
1 ocean ton = 40 ft³ = 1.1327 m³

Great Britain (UK)

1 min (minim) = 0.059194 cm³
1 fluid drachm = 60 min = 3.5516 cm³
1 fl oz (fluid ounce) = 8 fl drachm = 0.028413 l
1 gill = 5 fl oz = 0.14207 l
1 pt (pint) = 4 gills = 0.56826 l
1 qt (quart) = 2 pt = 1.13652 l
1 gal (gallon) = 4 qt = 4.5461 l
1 bbl (barrel) = 36 gal = 163.6 l

Units of dry measure:

1 pk (peck) = 2 gal = 9.0922 l
1 bu (bushel) = 8 gal = 36.369 l
1 qr (quarter) = 8 bu = 290.95 l

United States (US)

1 min (minim) = 0.061612 cm³
1 fluid dram = 60 min = 3.6967 cm³
1 fl oz (fluid ounce) = 8 fl dram = 0.029574 l
1 gill = 4 fl oz = 0.11829 l
1 liq pt (liquid pint) = 4 gills = 0.47318 l
1 liq quart = 2 liq pt = 0.94635 l
1 gal (gallon) = 231 in³ = 4 liq quarts = 3.7854 l
1 liq bbl (liquid barrel) = 119.24 l
1 barrel petroleum¹ = 42 gal = 158.99 l

Units of dry measure:

1 dry pint = 0.55061 dm³
1 dry quart = 2 dry pints = 1.1012 dm³
1 peck = 8 dry quarts = 8.8098 dm³
1 bushel = 4 packs = 35.239 dm³
1 dry bbl (dry barrel) = 7056 in³ = 115.63 dm³

CABLE SPLICING GUIDE

(Duracast joint kit)

Cable Size(mm) 2-4 core	duracast reference	length	Diameter	Min Cable Diameter	Max Cable Diameter
1.5	P0	185	32	6	20
2.5	P0	185	32	6	20
4	P0	185	32	6	20
6	P1	240	38	9	30
10	P1	240	38	9	30
16	P2	270	44	17	34
25	P2	270	44	17	34
35	P2.5	310	60	22	42
50	P2.5	310	60	22	42
70	P3	400	68	28	52
95	P3.5	432	86	32	56
120	P3.5	432	86	32	56
150	P4	550	100	36	65
185	P4	550	100	36	65
240	P4	660	140	48	80

3-PHASE FORMULAE

- (1)

Voltage drop = 1.72 x 1 x R
Where 1 = Line current per phase
R = Resistance of one core only
NB: For large 3-core cables carrying high alternating currents, the increased AC resistance due to skin effect must be allowed for
- (2)

kW = kVA x Power Factor
kW = $\frac{\text{LINE AMPS} \times \text{LINE VOLTS} \times 1.73 \times \text{POWER FACTOR}}{1000}$
- (3)

kVA = $\frac{\text{KW}}{\text{POWER FACTOR}}$
kVA = $\frac{\text{LINE AMPS} \times \text{LINE VOLTS} \times 1.732}{1000}$
kVA = $\frac{\text{ORSE POWER} \times 746}{1000 \times \text{EFFICIENCY} \times \text{POWER FACTOR}}$
- (4)

LINE AMPS = $\frac{\text{kW} \times 1000}{\text{LINE VOLTS} \times 1.72 \times \text{POWER FACTOR}}$
LINE AMPS = $\frac{\text{kVA} \times 1000}{\text{LINE VOLTS} \times 1.732}$
LINE AMPS = $\frac{\text{kW} \times 1000}{\text{LINE VOLTS} \times 1.72 \times \text{POWER FACTOR} \times \text{EFFICIENCY}}$

kW = KiloWatt kVA = KiloVolt Amps Power Factor = Cos θ

CONVERSIONS

1 HP	=	746 Watts
1 kW	=	1.341 HP
1 metre	=	39.37"
1"	=	25.4 mm
1 kg	=	2.2 lb
1 lb	=	0.4545 kg

RATE CURRENTS OF PVC
INSULATED COPPER CONDUCTORS

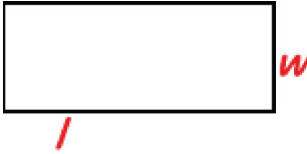
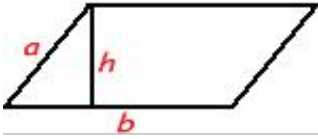
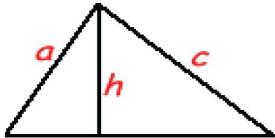
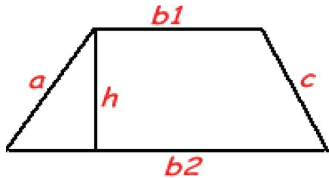
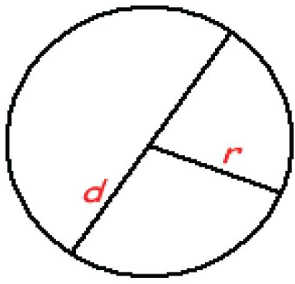
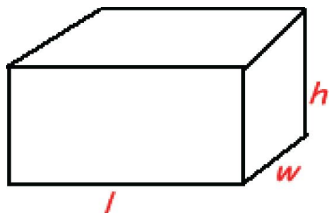
Rate area of conductor mm²	Safe current carrying capacity (A)
0.5	5
0.75	8
1.0	10
1.5	15
2.5	20
4.0	27

Conductor	CURRENT CARRYING CAPACITY AND ASSOCIATED VOLTAGE DROP OF CONDUCTORS							
C.S.A	60°C rubber isolated				90°C rubber insulated			
	1 two-core cable " or 2 single core cables touching		1 three-core four-core or fice-core cable		1 two-core cable" or 2 single-core cables touching		1 three-core four-core or five-core cable	
mm²	d.c. or single phase a.c.		three phase a.c.		d.c. or single phase a.c.		three phase a.c.	
	A	mV/A/m	A	mV/A/m	A	mV/A/m	A	mV/A/m
4	30	12	26	10	42	13.2	37	11
6	39	7.8	34	6.7	55	8.5	49	7.3
10	51	4.6	47	4.0	76	5.1	66	4.3
16	73	2.9	63	2.5	103	3.2	59	2.7
25	97	1.8d 1.85a	83	1.55	136	2.03d 2.04a	119	1.73
35	140	1.31d 1.32a	102	1.15	200	1.42d 1.46a	146	1.23
50	175	0.91d 0.93a	124	0.84	250	1.00d 1.02a	177	0.93
70	216	0.64d 0.67a	158	0.58	310	0.71d 0.73a	225	0.64
95	258	0.49d 0.53a	192	0.44	369	0.54d 0.57a	273	0.49
120	302	0.38d 0.43a	222	0.36	432	0.42d 0.46a	316	0.39
150	347	0.31d 0.36a	255	0.30	497	0.34d 0.39a	363	0.32
185	394	0.25d 32a	291	0.26	564	0.27d 0.33a	414	0.27
240	471	0.19d 0.27a	343	0.21	673	0.21d 0.28a	487	0.23
300	541	0.15d 0.24a	394	0.185	773	0.167d 0.25a	560	0.195
400	644	0.115d 0.21a	-	-	885	1.27d 0.22a	-	-
500	738	0.090d 0.20a	-	-	1017	0.100d 0.20a	-	-
630	861	0.68d 0.185a	-	-	1190	0.074d 0.190a	-	-

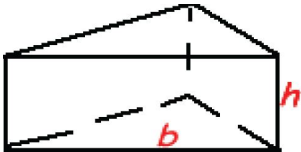
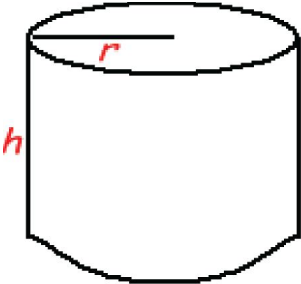
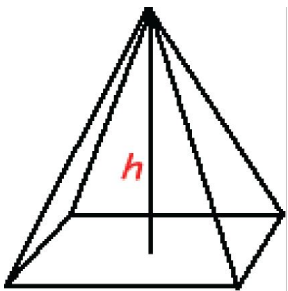
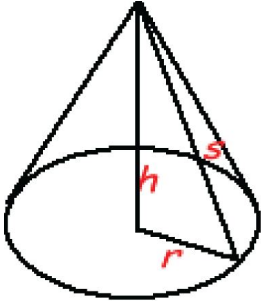
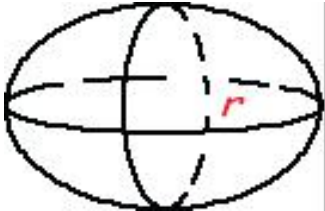
WIRE GAUGE SIZE AND AMPERAGE FOR FUSE CIRCUIT BREAKER FOR WATTS

Element Wattage	Phases	Circute Breaker Size (Amp)				Copper Wire Size in Gauge			
		208V	240V	277V	480V	208V	240V	277V	480V
3kW	1	20 A	20 A	15 A	15 A	12	12	14	14
	3	20 A	20 A	-	15 A	12	12	-	14
3.8kW	1	25 A	20 A	-	-	10	10	-	-
	-	-	-	-	-	-	-	-	14
4kW	1	25 A	25 A	20 A	15 A	10	10	12	14
	3	25 A	25 A	-	15 A	10	10	-	14
4.5kW	1	30 A	25 A	25 A	15 A	10	10	10	14
	3	30 A	25 A	-	15 A	10	10	-	14
5kW	1	30 A	30 A	25 A	15 A	10	10	10	14
	3	30 A	30 A	-	15 A	10	10	-	14
5.5kW	1	35 A	30 A	25 A	15 A	8	10	10	14
	3	35 A	30 A	-	15 A	8	10	-	14
6kW	1	40 A	35 A	30 A	20 A	8	8	10	12
	3	35 A	30 A	-	15 A	8	10	-	14
8kW	1	50 A	45 A	40 A	25 A	8	8	8	10
	3	45 A	40 A	-	20 A	8	8	-	12
9kW	1	-	50 A	45 A	25 A	-	8	8	10
	3	50 A	45 A	-	25 A	8	8	-	10
10kW	1	-	-	50 A	30 A	-	-	8	10
	3	-	50 A	-	25 A	-	8	-	10
11kW	1	--	50 A	30 A	-	-	8	10	
	3	-	50 A	-	25 A	-	8	-	10
12kW	1	-	-	-	35 A	-	-	-	8
	3	-	-	-	30 A	-	-	-	10

FORMULAS FOR PERIMETER, AREA, SURFACE, VOLUME

Shapes	Formulas
	Rectangle Area = Length X Width $A = lw$ Perimeter = 2 X Lengths + 2 X Widths $P = 2l + 2w$
	Parallelogram Area = Base X Height $A = bh$ Perimeter = add the length of all sides $P = 2a + 2b$
	Triangle Area = 1/2 of the base X the height $A = \frac{1}{2}bh$ Perimeter = $a + b + c$ (add the length of the three sides)
	Trapezoid Area = 1/2 of the base X the height $A = \left(\frac{b_1 + b_2}{2}\right)h$ Perimeter = add lengths of all sides $P = a + b_1 + b_2 + c$
	Circle Radius = the distance from the center to a point on the circle (r). Diameter = the distance between two points on the circle through the center ($d = 2r$). Circumference = the distance around the circle ($C = \pi d = 2\pi r$). (Assume $\pi \approx 3.14$) Area = πr^2
	Rectangular Solid Volume = Length X Width X Height $V = lwh$ Surface = $2lw + 2lh + 2wh$

FORMULAS FOR PERIMETER, AREA, SURFACE, VOLUME

Shapes	Formulas
	Prisms Volume = Base X Height $V = bh$ Surface = $2b + Ph$ (b is the area of the base P is the perimeter of the base)
	Cylinder Volume = πr^2 X height $V = \pi r^2 h$ Surface = 2π radius X height $S = 2\pi rh + 2\pi r^2$
	Pyramid Volume = $\frac{1}{3}$ area of the base X height $V = \frac{1}{3}bh$ b is the area of the base Surface Area: Add the area of the base to the sum of the areas of all of the triangular faces. The areas of the triangular faces will have different formulas for different shaped bases.
	Cones Volume = $\frac{1}{3}$ area of the base x height $V = \frac{1}{3}\pi r^2 h$ Surface $S = \pi r^2 + \pi rs$ $= \pi r^2 + \pi r \sqrt{r^2 + h^2}$
	Sphere Volume $V = \frac{4}{3}\pi r^3$ Surface $S = 4\pi r^2$





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