Application Description AD/TEMP/001–EN

Temperature measurement
Nuclear power reactors

The ultimate in sensor quality where you want it most

Introduction

Global warming, worries over the security of supply of fossil fuels, the need for reliable base load electrical energy, a growing world population; all are leading many countries to consider the need for nuclear power generation. The existing stock of nuclear power plants is not insignificant and they all need sophisticated temperature measurement to remain efficient and, above all, safe.

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World nuclear power plant distribution

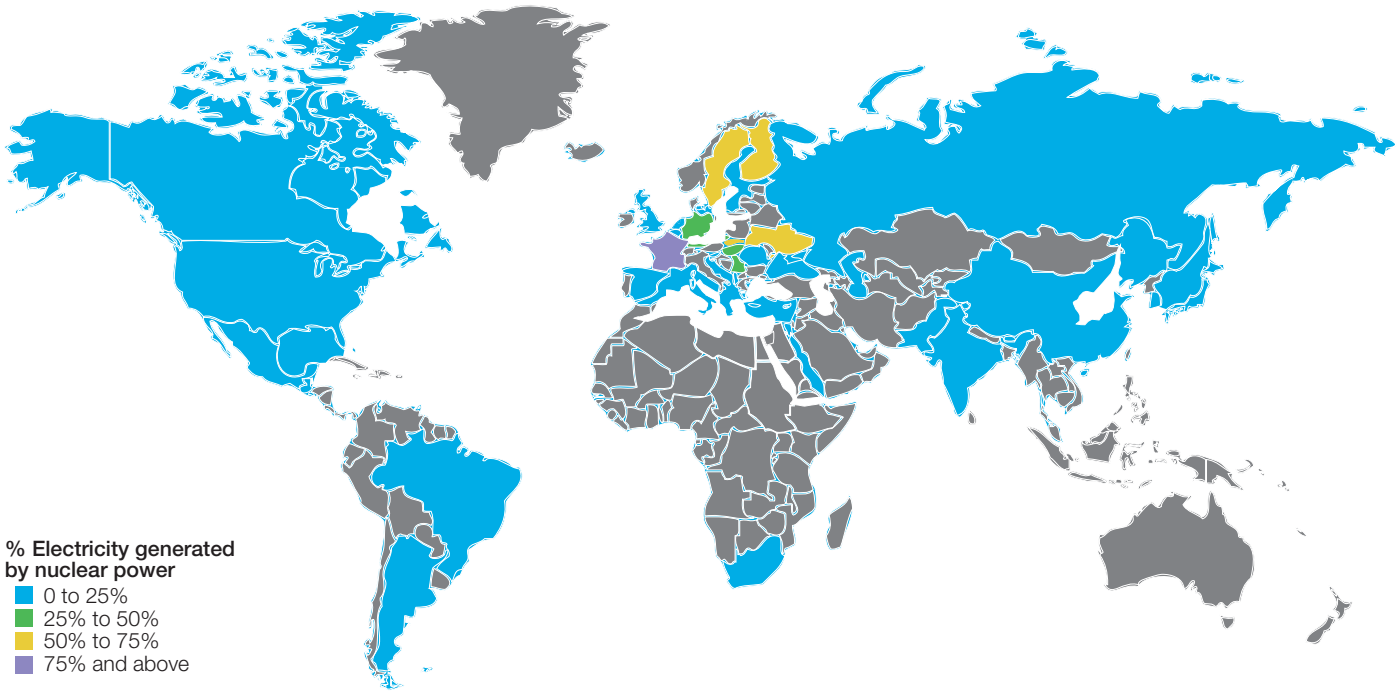

Fig. 1 World locations of nuclear power reactors

World nuclear power reactors

- There are 439 operational reactors in the world providing 13.8 % of the world's electrical power.
- 62 reactors are currently under construction with a further 484 reactors planned or proposed to be operational by 2030.
- The number of reactors shown in Fig. 1 is significant but the most interesting fact is that more new reactors are planned than currently exist.

Reactors and their need for temperature measurement

There are a number of designs of nuclear reactor but the most common by a significant margin is the Pressurised Water Reactor (PWR). The PWR uses water as a reactor coolant in the primary circuit and as a neutron moderator (slowing the neutrons to enable them to produce the chain reaction required to produce power). All nuclear power stations operate by producing large amounts of energy in the form of heat; nuclear reactions produce significantly more heat from each kilogram of fuel than conventional chemical reactors (coal, oil or gas burning). The heat generated by the reactor must be removed to provide steam to drive turbines in exactly the same way as their chemical burning equivalents. Just like a conventional power station, failure to remove the heat generated results in dangerously high temperatures in the reactor. The difference between a conventional power station and a nuclear power station are the potential consequences of such an occurrence – 'melt down'.

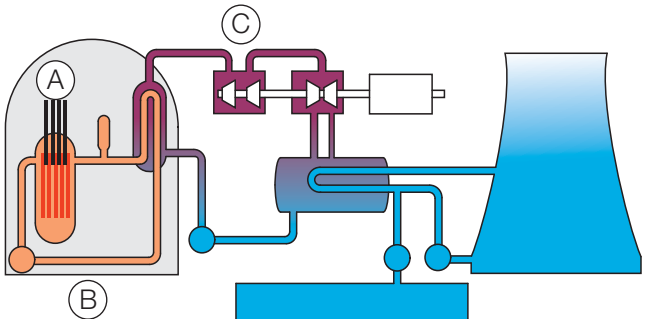

Fig. 2 Simplified PWR power station schematic

Fig. 2 shows a simplified schematic of a PWR power station. Outside a structure known as the containment building, a PWR power station looks much like any other. The containment building houses the major difference; it is here where the conventional boiler is replaced by a reactor. The heat generated by the reactor is controlled by special rods (A) that absorb neutrons and slow the nuclear reaction. A sealed primary circuit (B) contains water under high pressure (to prevent it from boiling) that is used to cool the reactor. The heat absorbed by the primary circuit is transferred to a secondary circuit (C) that delivers this heat in the form of super-heated steam to drive the turbines coupled to the generators that produce the electrical power.

Temperature measurement is vital to both the efficient and safe operation of this heat-powered system. Measurements made in the secondary circuit or the cooling tower circuit are conventional in nature and can therefore be considered as conventional temperature measurement, even though they obviously have an influence on the efficient and safe running of the plant. It is temperature measurement in the primary circuit where things become much more interesting.

Primary circuit temperature measurement

Temperature measurement in the primary circuit of a nuclear reactor presents some significant challenges:

- the sensing element must be capable of a rapid response (typically less than 2.2 seconds [t 0.63])
- the sensing element must be highly accurate
- it must be possible to replace the sensing element without draining the primary circuit
- the measurement system must be capable of operating:
  - at temperatures of up to 400 °C (752 °F)
  - at a pressure of 170 bar (2465 psi)
  - in flow rates of 15 meters (49 feet) per second.
- a unique requirement is to withstand the high radiation levels in the primary circuit

All nuclear power plant equipment must be certified to exacting standards, for example, IEEE 323 / 344.

ABB has qualified sensor technologies including designs for use in PWR primary loops. Thermowells manufactured from a single piece of stainless steel (316TI) with a reduced tip diameter of 5.65 mm (0.22 in.) enable the fast response needed. The sensing element is a PT200 in four-wire connection with flying leads protected by flexible, stainless steel armored sheathing. The measuring element can be removed for exchange during operation.

It will come as no surprise to know that each measurement point in the primary circuit is covered by significant device redundancy, so each point will have three or more measurement systems installed.

ABB requirements for supply to the nuclear industry

A common misconception is that ABB is not permitted to supply equipment to the nuclear industry. This is simply not true. There are, however, significant restrictions and procedures that must be followed before quoting to a nuclear plant. Please consult with your legal team.

ABB temperature measurement

Your temperature PLS can advise on all aspects of temperature measurement and are ready to assist you with all your customer's needs.

Contact us

ABB Limited
Process Automation
Salterbeck Trading Estate
Workington, Cumbria
CA14 5DS
UK
Tel: +44 (0)1946 830 611
Fax: +44 (0)1946 832 661

ABB Automation Products GmbH
Process Automation
Schillerstr. 72
32425 Minden
Deutschland
Tel: +49 551 905 534
Fax: +49 551 905 555

www.abb.com

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AD/TEMP/001-EN 10.2011

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