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CHILLER PLANT MEASUREMENT & VERIFICATION

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Agenda

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1. Chiller Plant Measurement & Verification
2. Temperature Measurement
3. Flow Measurement
4. Power Measurement
5. Total Uncertainty and Heat Balance

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CHILLER PLANT MEASUREMENT & VERIFICATION

	Accuracy	Before	After
Flowmeter – Magnetic Type	± 0.5%	5D	2D
– Ultrasonic	± 1.0%	10D	5D

Green Mark requirements

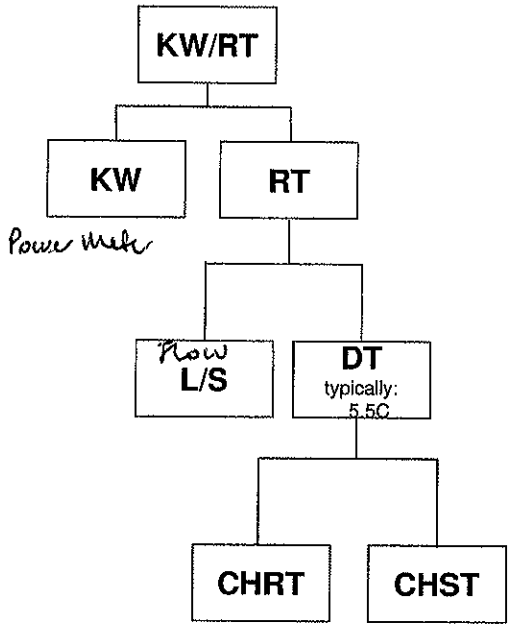
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- GM V4.1 for New Buildings and GM V3.0 for Existing Buildings.
- A pre-requisite for permanent instrumentation to measure chiller plant efficiency to accuracy of +/- 5% plus additional requirements below:

1) Location and installation of instruments to meet manufacturer's recommendations. – straight pipe before & after flowmeters.
2) Data acquisition system to have minimum A/D resolution of 16bit.
3) All data logging with capability to trend at 1 minute time interval.
4) Flow meters are to be provided for chilled water and condenser water loop and shall be of ultrasonic / full bore magnetic type or equivalent.
5) Temperature sensors are to be provided for chilled water and condenser water loop and shall have an end-to-end measurement uncertainty not exceeding +/- 0.05C over the entire measurement or calibration range. – Pair sensor, logger + etc. All thermo-wells shall be installed in a manner that ensures that the sensors can be in direct contact with the fluid flow. Provision shall be made for each temperature measurement location to have 2 spare thermo well located at both side of the temperature sensor for verification of the measurement accuracy.
6) Dedicated power meters are to be provided for each of the following equipment: Chillers, chilled water pumps, condenser water pumps and cooling towers.

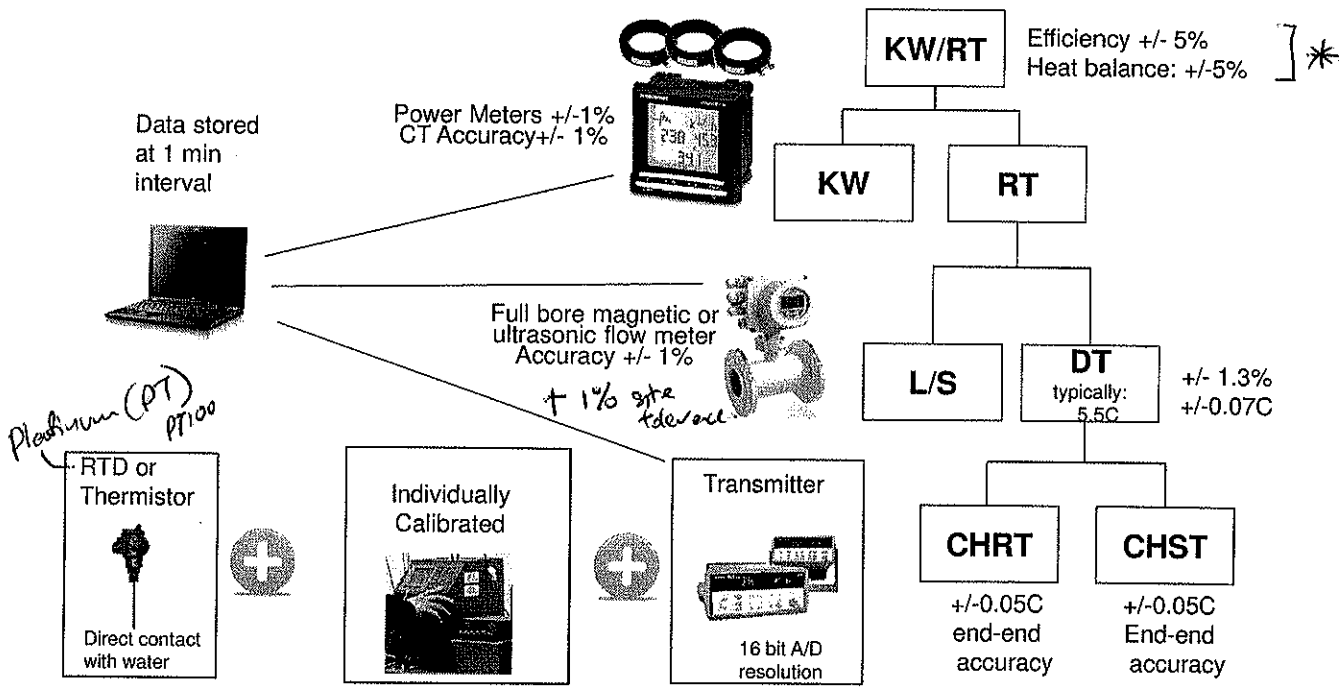
Measuring chiller plant efficiency

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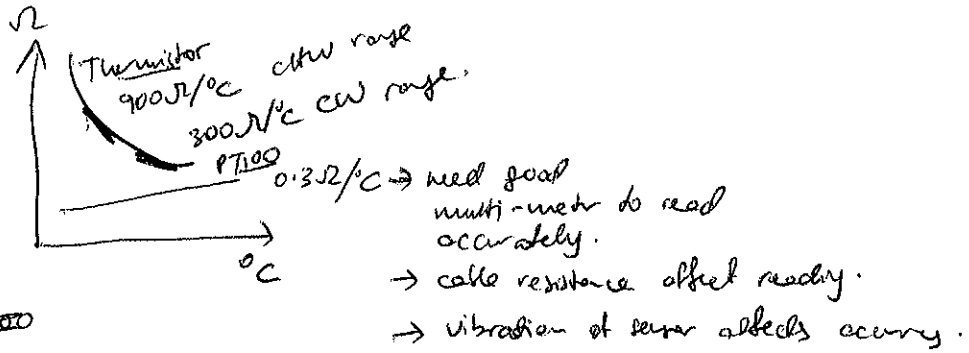
Instrument Accuracy

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TEMPERATURE MEASUREMENT



Temperature Measurement

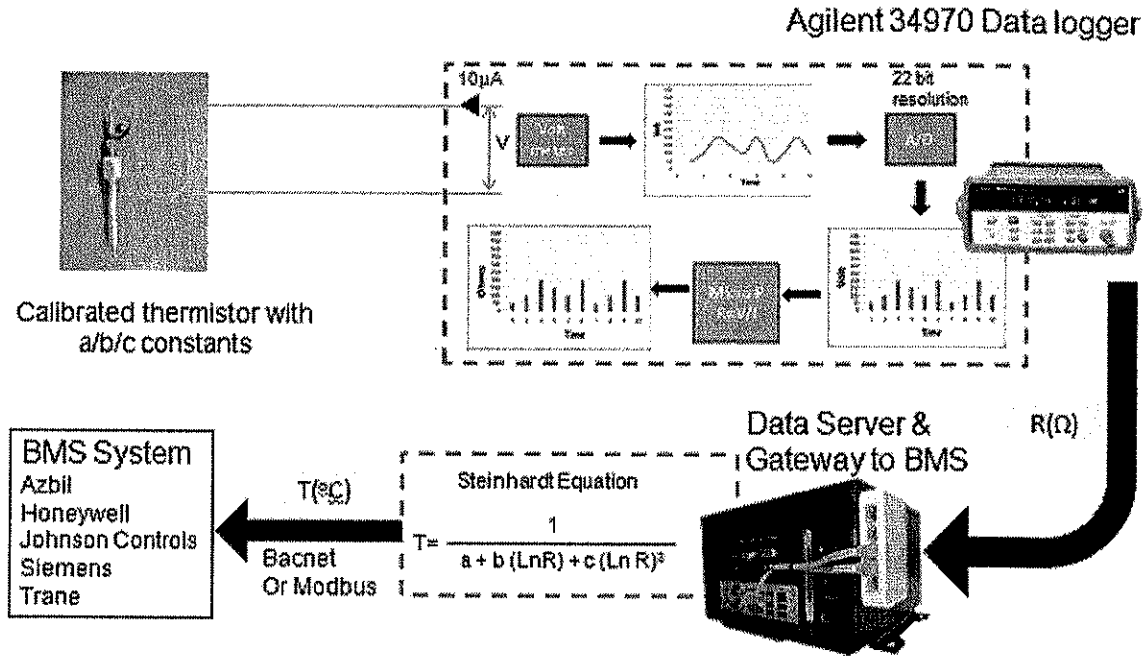
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recommended.

	Resistant temperature detectors (RTD) PT100	Thermistors
Principle of operation	It exploits the predictable change in electrical resistance of some materials with changing temperature. Most commonly used material is Platinum and they are commonly called PRT or PT.	Like RTD, it also exploits the predictable change in electrical resistance with temperature. Thermistors are made from certain metal oxides whose resistance decreases with increasing temperature.
Accuracy	They have positive temperature coefficient. It is very accurate and nearly linear. Characterised by Callendar-van Dusen equation $R = r(\Omega @ 0C) \times (1 + aT + bT^2)$ Resistance of PT (100 Ω at 0C) is relatively low so lead wire resistance becomes significant. 3 or 4 wire PT is therefore required. Exhibit a small change in resistance for a change in temperature. (eg 0.3 Ω / C) With proper calibration, uncertainties of better than 0.01°C can be achieved.	They have negative temperature coefficient. It is very accurate but non linear. Characterised by Steinhardt equation $1/T = a + b(\ln R) + c(\ln R)^3$ Resistance is high (eg 10,000 Ω at 25C) so lead wire becomes insignificant. 2 wire thermistor is usually adequate. Exhibit a large change in resistance for a change in temperature. (eg 300 Ω / C for CW and 900 Ω / C for CHW) With proper calibration, uncertainties of better than 0.01°C can be achieved.
Cost	High	Medium

Temperature Measurement Chain

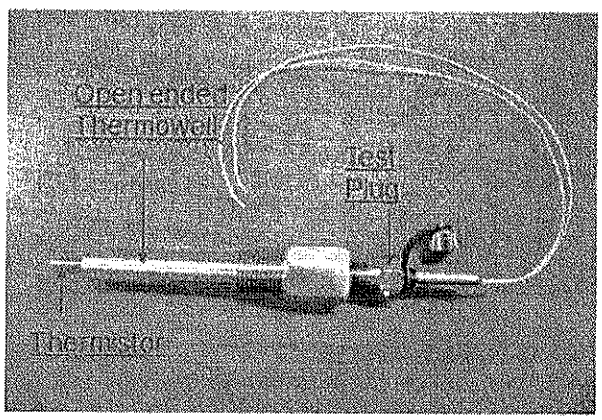
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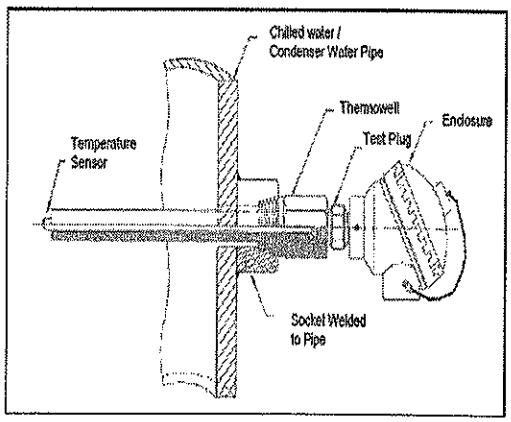


Thermistors Direct Contact with Fluid

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- To improve accuracy and response time.





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FLOW MEASUREMENT

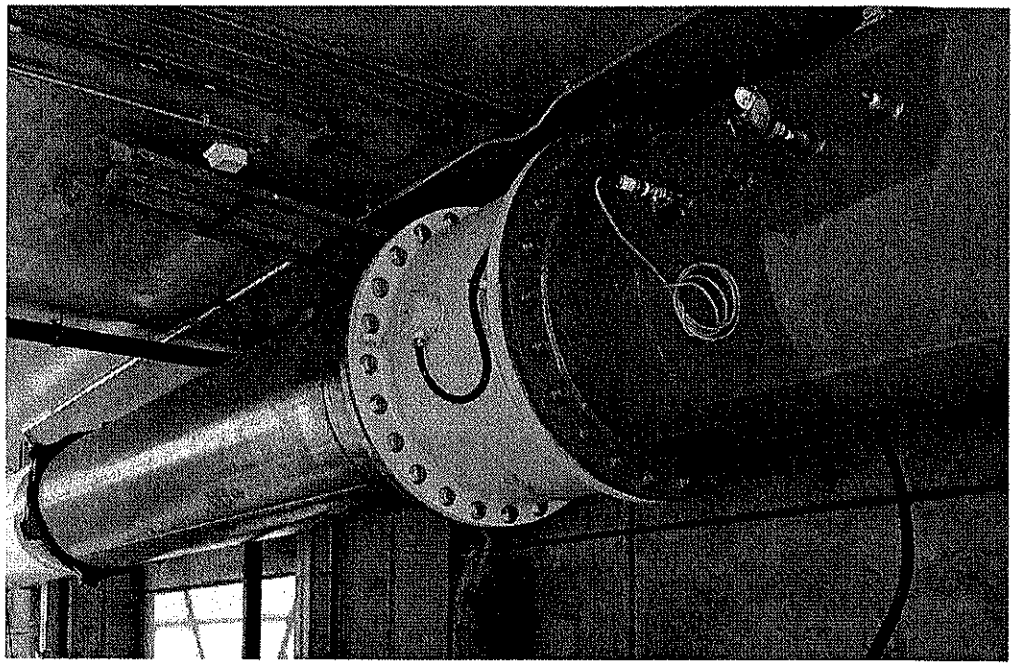
Flow Measurements

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	Full bore magnetic flow meter	Ultrasonic clamp on flow meter
Principle	The principle of operation is based on the Faraday Law which states that a voltage is created as conductor moves through a magnetic field. The fluid is the conductor in this case. The voltage created is proportional to the velocity of the fluid.	The principle of operation is based on sound transit time in a moving fluid. The sound transit time in the direction of flow is faster than the sound transit time in the opposite to the direction of flow.
Accuracy	0.5-1%	1-2%
Price	Depends on the diameter Diameter 200mm (8"): S$3-4k Diameter 700mm (28"): S$10-12k	S$ 5-6k
Brands	ABB Endress & Hauser Siemens	GE Panametrics Endress & Hauser Siemens

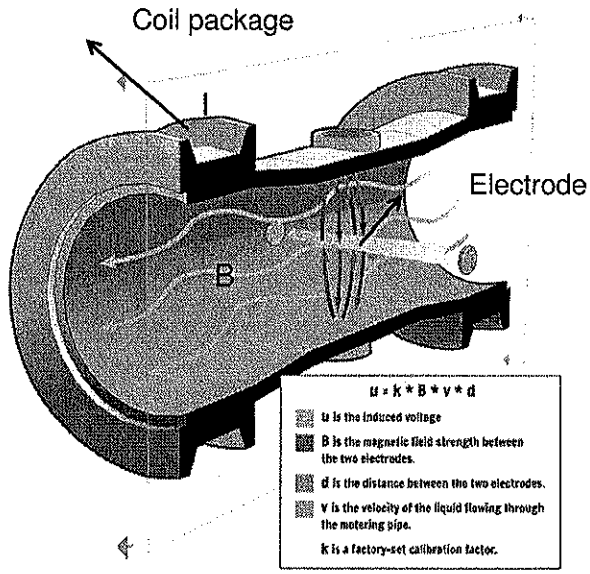
Full Bore Electromagnetic Flow Meter

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Full Bore Electromagnetic Flow Meter

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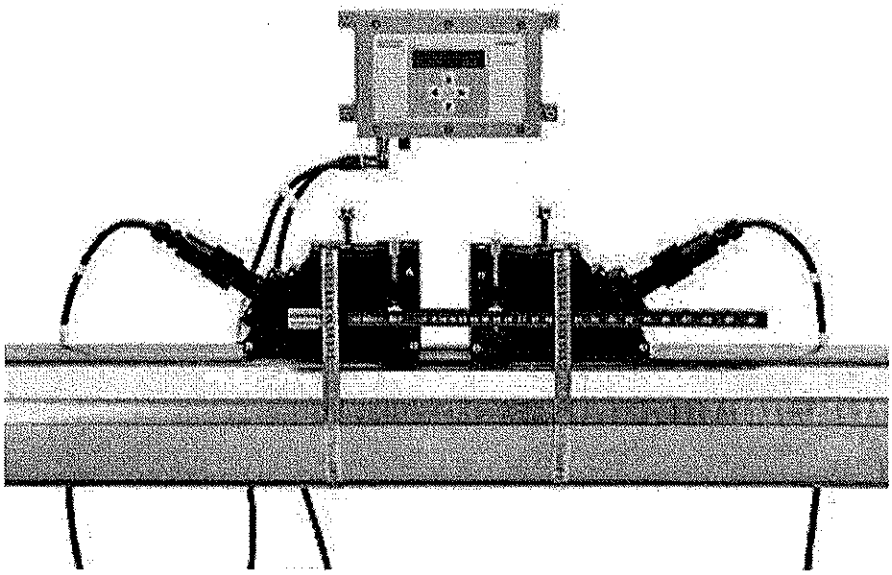
The principle of operation for the magnetic flowmeter is based on the Faraday's Law of Electromagnetic Induction.

An electrical current (I) is applied to a coil package inside the flowmeter. As a result, a magnetic field (B) is created across the metering pipe.

When a conductive liquid flows through the magnetic field, a small voltage (V) is induced. This voltage is proportional to the velocity of the flow and is accurately measured by two stainless steel electrodes mounted opposite each other inside the metering pipe. The two electrodes are connected to an advanced electronic input circuitry which processes the signal and in turn feeds it to the a microprocessor inside the electronics module. The microprocessor then calculates the volumetric flow and controls the various outputs on the terminal board.

Ultrasonic Clamp-on Flow Meter

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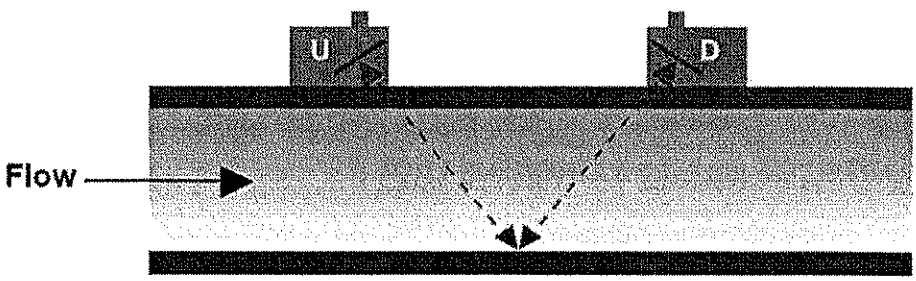


Ultrasonic Clamp-on Flow Meter

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↳ Accuracy affected by pipe condition, eg corrosion, pipe dimensions

- The measuring principle of ultrasonic flow meter is based on ultrasound transmission through a liquid. Transit time measuring technique utilizes two transducers, which function as both ultrasonic transmitters and receivers. The ultrasound waves traveling in the direction of the flow of the liquid require less time than when traveling in the opposite direction, therefore the difference in time taken by the ultrasonic waves to travel over the same distance but in opposite directions is an indication of the velocity of the liquid.



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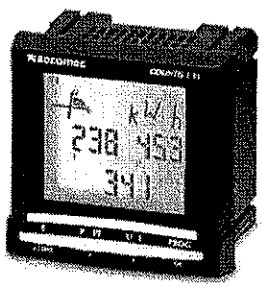
POWER MEASUREMENT

Power Measurement

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Class 1



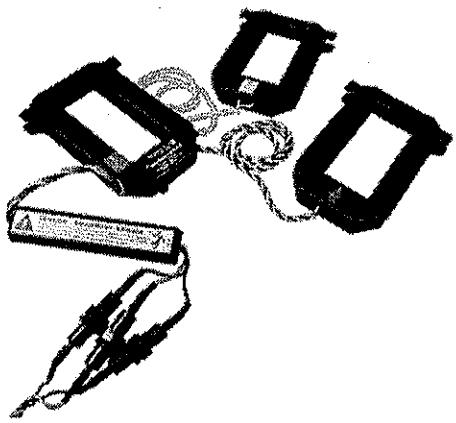
Class 1

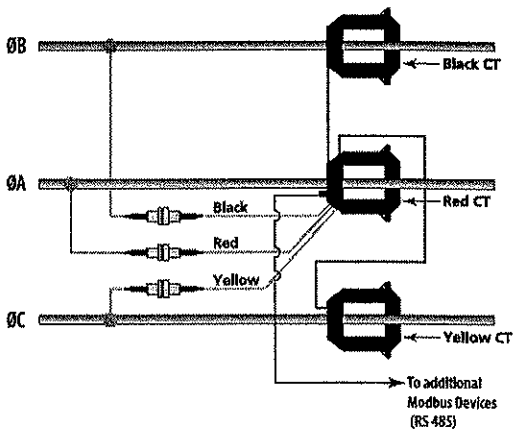
Usually Class 0.5 since no price diff

Power Meter

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- Use integrated meter (Power meter and CT by same supplier) to measure Volt, Amps & PF
- True RMS power





Integrated Power Meter Specifications

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SPECIFICATIONS

Input Primary Voltage	208 to 480VAC RMS[†]
Number of Phases Monitored	One to Three
Frequency	50/60Hz
Primary Current	Up to 2400 amps cont. per phase[††]
Internal Isolation	2000VAC RMS
Insulation Class	600VAC RMS[†††]
Temperature Range	0° to 60°C (32°F to 140°F), 50°C (122°F) for 2400A
Humidity Range	0 - 95% non-condensing
Systems Accuracy	±1% of reading from 10% to 100% of the rated current of the CTs...accomplished by matching the CTs with a meter and calibrating them as a system
Output Physical Characteristics	RS-485, 2 wire + shield
Baud Rate	9600, 8N1 format
Protocol	Modbus RTU**(*)

Data output:
- kWh, Consumption
- kW, Real Power
- kVAR, Reactive power
- kVA, Apparent power
- Power factor
- Average Real power
- Minimum Real power
- Maximum Real power
- Voltage, line to line
- Voltage, line to neutral[†]
- Amps, Average current
- kW, Real power ØA[†]
- kW, Real power ØB[†]
- kW, Real power ØC[†]

[†] Based on derived neutral voltage.

Errors in Power Measurement

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- Power meters that are not integrated with CT may be prone to error due to wrong settings.
- For example, an energy audit revealed that power measurement error existed in BAS for 15 years because of a wrong CT ratio setting.



Class 1

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MEASUREMENT UNCERTAINTY AND HEAT BALANCE

Measurement uncertainty

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$\sqrt{1^2+1^2} = \pm 1.4\%$

- Root Sum Square Method

①

Power meter uncertainty	+/- %	1.0%
Current transformer uncertainty	+/- %	1.0%
Total power measurement uncertainty	+/- %	1.4%

②

Flow meter uncertainty	+/- %	1.0%
Site installation error allowance	+/- %	1.0%
Total flow measuremnt uncertainity	+/- %	2.0%

③

Temperature sensor end-to-end uncertainty	+/- C	0.05
DT temperature measurement uncertainty	+/- C	0.071
CHW design DT	C	5.5
CHW DT measurement uncertainity	+/- %	1.3%

$\sqrt{0.05^2+0.05^2} = \pm 0.071\,^{\circ}C$

$\% = \frac{0.071}{5.5} = \pm 1.3\%$

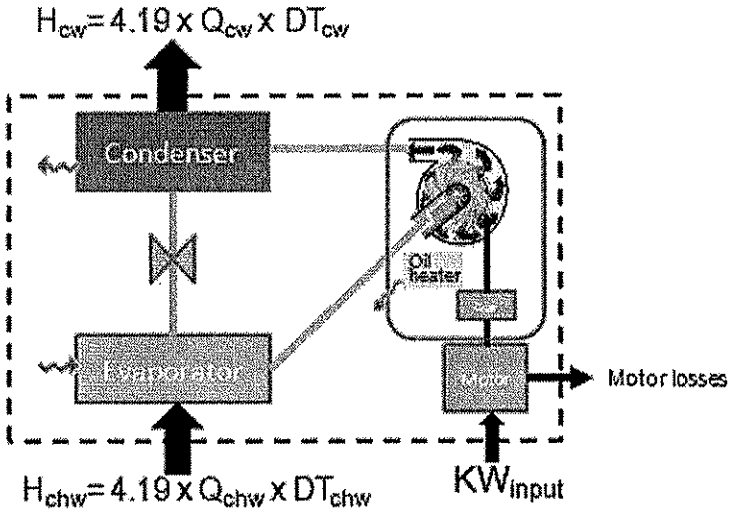
Total KW/RT measurement uncertainity	+/- %	2.8%

$\sqrt{1.4^2+2.0^2+1.3^2} = \pm 2.8\%$

Heat Balance Validation Check

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⇒ to validate sensor accuracy.



Energy in = Energy out

$(4.19 \times Q_{chw} \times DT_{chw}) + (KW_{input} - \text{Motor losses}) = 4.19 \times Q_{cw} \times DT_{cw}$

Heat Balance Validation Check

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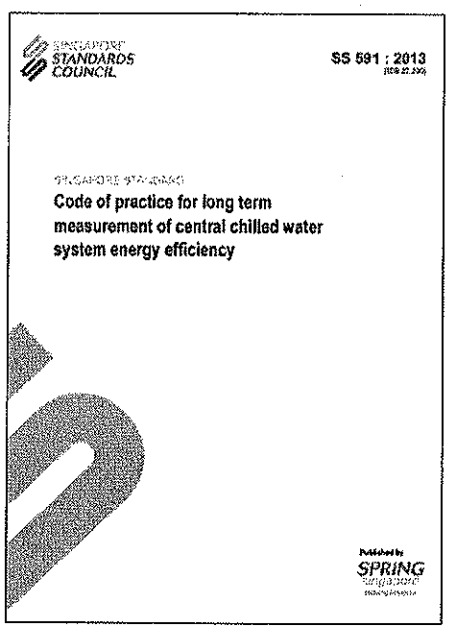
$$\frac{\text{Heat input} - \text{Heat output}}{\text{Heat output}} <= 5\%$$

* 80% of data point must fall with +/-5% for 1 week operating period .

Hotel 24 hours for 7 days
Office 9-6pm for 5 days
Shopping 10a-10pm for 7 days.

For more information

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Chiller Plant Measurement & Verification Course (3.5 days)

THANK YOU

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