TOTAL DISSOLVED SOLIDS MEASUREMENT

Total Dissolved Solids

Definition: Total Dissolved Solids (TDS) is a measure of the sum of all inorganic and organic substances in a liquid in molecular, ionized or micro-granular colloidal suspended form. The solids must be small enough to survive filtration through a sieve the size of two micrometer.

TDS solids are normally found in all freshwater systems. Major applications of TDS are: at low levels the study of water quality for streams, rivers, lakes, potable water taste, and at high levels the control of scale in recirculating water systems. It is a quality indicator for drinking water and is a general measure of the presence of chemicals. In seawater RO desalination, TDS provides a way of comparing the feed with the permeate quality that is relevant to drinking water taste standards.

Illustration: 210-C analyzer configured to measure TDS.

Where does TDS come from?

TDS in surface waters come from the solvent action of water in contact with minerals in the earth, agricultural and residential runoff, leaching of soil contamination, and used water from industrial or sewage treatment plants. Common chemical constituents are calcium, sodium, chloride, potassium, phosphates and nitrates. They may be cations, anions, molecules or agglomerations of molecules, so long as they are soluble. The United States and Canada have a secondary water quality standard of 500 mg/L TDS or less for palatable drinking water. Water with TDS of greater than 500 mg/L may have poor taste and when over 1500 mg/L will taste like weak Alka-Seltzer® to most people.

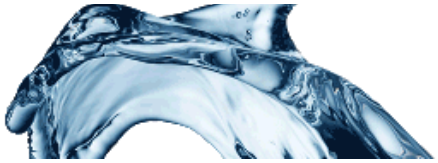
Total Suspended Solids (TSS), are different from TDS as they cannot pass through a sieve of two micrometers and are suspended in solution. Flocculation and sand filtration can remove settle-able solids and suspended solids from the water but dissolved TDS solids are not removed.

TDS in Water Systems

TDS enters recirculating water systems with the water supply from municipal, lake, river, or well water. Once inside evaporation of a portion of the recirculating water concentrates TDS solids. High TDS levels generally indicate hard water, water hardness must be removed or will cause scale buildup in pipes, valves, and filters, reducing performance and adding to boiler system maintenance and efficiency costs. TDS is frequently tested manually and by continuous TDS analyzer which operates a blowdown valve to keep the system below the scale deposition concentration.

These effects can also be seen in aquariums, spas, swimming pools, and reverse osmosis water treatment systems. Typically, in these applications, TDS is tested manually frequently or by continuous TDS analyzer, plus equipment and filtration membranes are inspected for deposits.

In aquaculture, TDS is monitored to create a water



quality environment suitable for the organism. For freshwater oysters, trouts, and other high value seafood, highest productivity and economic returns are achieved by mimicking the TDS and pH levels of each species' native environment.

In hydroponics, total dissolved solids is considered one of the best indicators of nutrient availability for the plants being grown.

TDS Measurement Methods

There are two principal methods of measuring total dissolved solids: gravimetic and conductivity. The standard method is gravimetric, which is considered the most accurate and involves evaporating the sample to dryness at 103 °C, then to 180 °C to remove any occluded water, (water molecules trapped in mineral matrix), then weighing it with a precision analytical balance (normally capable of 0.0001 gram accuracy). This method is generally considered best, although it is slow and has inaccuracies from low-boiling-point chemicals which evaporate with the water.

TDS of water is directly related to the conductivity of dissolved ionized solids in the water. Ions from the dissolved solids create the ability for water to conduct an electrical current, which is measured by the IC Controls 210-C(TDS) analyzer, and immediately displayed as sodium chloride ppm or mg/L or µS/cm conductivity. When periodically standardized with IC Controls TDS standards or by laboratory gravimetric TDS measurement, TDS analyzers based on conductivity provide a quick accurate value of the TDS.

TDS in Boilers

As a boiler generates steam, TDS impurities which are in the feedwater do not boil off with the steam. TDS impurities concentrate in the boiler water, building up to produce scale just like in a kettle. As the dissolved solids become more concentrated, the steam bubbles formed are more stable, failing to pop when they reach the water surface in the boiler. Eventually depending on boiler pressure, size, and steam load, some of the steam space in the boiler fills with bubble foam which may get carried over into the main steam pipe. This is dangerous because now the steam is wet as it leaves the boiler, en-training bubbles filmed by high-TDS boiler water. The TDS solids will contaminate control valves, heat exchangers, steam traps, and turbines.

The most common cause of carryover is a high Total Dissolved Solids (TDS) level. Foaming can also be caused by high levels of suspended solids, high alkalinity or contamination by oils and fats. Continuous control of boiler water TDS levels, plus periodic checks for contaminants should ensure minimal risk of foaming and carryover.

To avoid carryover, boiler manufactures typically specify maximum TDS based on operating pressure. For drum type boilers:

Drum Pressure PSIG	Max Boiler Water TDS
Up to 300	700 to 3500 ppm (mg/L)
from 300 to 450	600 to 3000 ppm (mg/L)
from 450 to 600	500 to 2500 ppm (mg/L)
from 600 to 750	200 to 2000 ppm (mg/L)
from 750 to 900	150 to 1500 ppm (mg/L)
from 900 to 1000	125 to 1250 ppm (mg/L)
from 1000 to 1800	100 ppm (mg/L)

Too high TDS, besides carryover, can result in scale deposits on the boiler heat surfaces. Regardless of the type of scale deposited boiler heat surfaces all exhibit a lowered ability to transmit heat. Studies publisher by water treatment chemical companies have shown that 3 mm (0.125 inch) of scale thickness causes about 2 to 3 % boiler efficiency loss. Not only does it add directly to the fuel bill, but also the slowed heat transfer from hot gas to boiler water results in higher temperature in the tube metal, and possible tube failure, boiler outage, and costly repairs.

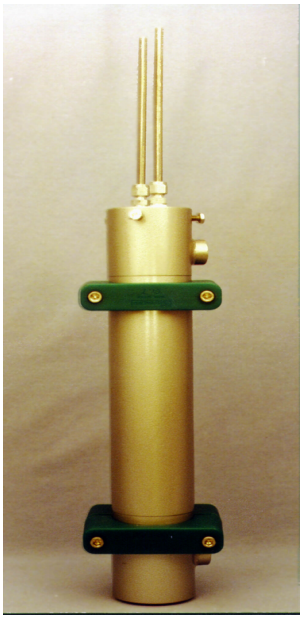
However, when TDS is measured on line by the IC Controls 210-C(TDS) analyzer, and continuously displayed as ppm TDS or mg/L or can also be displayed as µS/cm conductivity, there is reason to expect scale deposition can be avoided. When TDS is measured on line and control (blowdown) automated with the TDS set point set in consultation with your boiler specialty chemical supplier, scale deposits can be eliminated, saving fuel and maintenance costs.

Grab sampling for off line analysis

Even with continuous TDS monitoring, periodic samples should be collected as a check, plus with gravimetric analysis it can be used to standardize the TDS analyzer. Standardizing adjusts the TDS solids content factor, which can change with changes in water supply source or chemical treatment. When collecting a sample it is important to ensure that you get a representative sample. Boilers have a connection for surface or TDS blowdown, which is a good place to obtain a representative sample. Samples from close to the boiler feedwater inlet could give a false reading. Samples from level gauge glasses or external control chambers may contain condensate and should be avoided.

If sample water is simply drawn from the boiler, it will violently flash to steam as its pressure is reduced. Not only is this potentially very dangerous to the operator, but any subsequent analysis will also be wrong due to the loss of the flashed steam concentrating the sample.

To get a cooled sample for analysis, a sample cooler such as the IC Controls 501 (see nearby illustration) will be required. The 501 sample cooler is a small heat exchanger that uses cold water to cool the boiler water sample below the flash point.



Sample Cooler 501

What is meant by neutralized conductivity?

Boiler water typically contains hydroxyl (OH^-) ion alkalinity from high pH. The OH^- ion has very high conductivity but is a dissociate of H_2O so does not contribute to TDS. The OH^- ion conductivity can be eliminated by reducing the pH to 7 or neutralizing the sample with an organic acid such as gallic or acetic acid. Organic acids contribute a negligible amount to conductivity of water in the boiler.

What is the relationship between TDS and conductivity?

TDS ions from dissolved solids create the ability for water to conduct an electrical current, which is measured by the IC Controls 210-C(TDS) and immediately displayed as sodium chloride ppm or mg/L, or as a conductivity analyzer displayed as µS/cm. When directly measured in process the conductivity detected is not neutralized. IC Controls 210-C has an adjustable SCF solids content factor to match your application.

Typical non neutralized TDS solids content factors:
TDS as NaCl: 0.47 to 0.50
TDS as 442®: 0.65 to 0.85
TDS as KCl: 0.50 to 0.57

Typical neutralized TDS Conversion Factors:
TDS as NaCl: 0.70 to 0.75
TDS as KCl: 0.74 to 0.84

Water treatment chemicals and dispersant can cause significant variations specific to each plant. In the more concentrated boiler water the solids content factor typically is found between 0.55 and 0.9 ppm TDS per µS/cm. The water treatment company should be consulted and periodic gravimetric TDS tests done to confirm the solids content factor is stable.

What is the difference between ppm and mg/L?

Parts per million TDS or ppm (abbreviated) is an expression of quantity, mg/L (milligrams per liter) is an expression of weight. Both are used as scales for TDS, but ppm is more popular. There is no conversion factor since 1 ppm = 1 mg/L.

How can you calibrate a TDS analyzer?

Two ways:

1) The gravimetric method is considered the most accurate and involves evaporating the sample to dryness at 103 °C, then to 180 °C to remove any occluded water, then weighing it with a precision balance capable of 0.0001 gram. Gravimetric analysis is best, although slow, and has inaccuracies from evaporation of low boiling point chemicals. Use the result to adjust the TDS analyzer's solids content factor to achieve the reading.

2) By use of known TDS standards. IC Controls offers TDS standards as sodium chloride ppm or mg/L, made with NIST SRM traceable materials. Calibration becomes simply a mater of dipping the TDS sensor into the selected standard and calibrating.

Illustration: TDS Standards

TDS Standards, traceable to NIST SRM from IC Controls; made following ASTM D1125:

A1100244 70.1 ppm or mg/L as NaCl at 25ºC
A1100243 700 ppm or mg/L as NaCl at 25ºC
A1100242 7217 ppm or mg/L as NaCl at 25ºC
A1100241 74380 ppm or mg/L as NaCl at 25ºC
For maximum precision these standards include a table of their values at different temperatures. This allows the user to achieve quality calibrations through all temperatures encountered in the field.

Equivalent TDS standards from IC Controls:
A1100245 47 ppm or mg/L as NaCl at 25ºC
A1100246 692 ppm or mg/L as NaCl at 25ºC
A1100247 7230 ppm or mg/L as NaCl at 25ºC
for maximum precision these standards include a table of their values at different temperatures. This allows the user to achieve quality calibrations through all temperatures encountered in the field.

IC Controls
Process Water Analysis Equipment since 1979

Thermo SCIENTIFIC
Canadian Distributor of Orion Process Since 1981

What to Order for Boiler TDS monitoring

1 TDS analyzer, 210-C(TDS)-1-10-20 Recommended options: TDS Standards
1 TDS sensor, 401-2.0-62 A9200000 Sensor Signal to Analyzer Cable

210-C(TDS): Analyzer

Benefits - Solid metal Boiler House survivor housing
- Display shows TDS, temperature, 4 alarms, 2 4-20 mA
- Display as neutralized TDS, or non-neutralized TDS
- TDS display units available are ppm, mg/L, or ppt
- SCF factor adjustable between 0.40 - 1.10
- Easy calibration - recognizes standards, holds outputs
- Self- and sensor diagnostics
- 4-20 mA outputs: 1 for TDS, 1 for Temperature
- 4-20 mA limits direct set in ppm or mg/l TDS
- Four programmable alarms with self- and sensor alert
- ON-OFF control and/or pump pulser control
- TDS set point units direct set in ppm, mg/L, or ppt
- Optional PID control
- Optional communications

Model 401-2.0-62: TDS Sensor, cond. based

Benefits - Solid metal Boiler House survivor housing
- Rugged TDS Sensor with Explosion Proof Housing
- Rapid and accurate TDS, or non-neutralized TDS
- Easy calibration – in air and TDS Standards
- Easy in line Standardize – with Grab Samples
- Operating temperature to 200°C (392°F) maximum
- Operating pressure to 2.8 MPa (400 psi) maximum
- Automatic temperature compensation
- Constructed of 316 SS, EDPM, and PEEK
- Direct insertion, 3/4" NPT screw in design
- Low maintenance

Option 1 **501 Sample Cooler**

Model 501: Sample Cooler

Benefits - 316 SS Boiler House Cooler
- Cools high temperature liquids to safe handling Temp.
- Boiler water, feed water, steam, chemical solutions
- Rapid and accurate TDS grab samples
- Energy efficient counter flow design
- Easy coil removal for inspection or scale removal
- Safe continuous sample tube from inlet to outlet
- Operating temperature to 316°C (600°F) max.
- Operating pressure to 20.7 MPa (3000 psi) max.
- 1/2" cooling water connections, for 5 GPM
- Constructed of 316 SS
- 680 cc/min (90 lb/hr) water
- 525 cc/min (70 lb/hr) steam
- Low maintenance
- Optional high temp/pressure sample throttling valve

Option 2 **TDS Standards**

Benefits
- Calibration is easy, no long time delay
- range of values available
- includes table of values at various temperatures

Can be traced to NIST
- A1100244 70.1 ppm or mg/L as NaCl at 25ºC
- A1100243 700 ppm or mg/L as NaCl at 25ºC
- A1100242 7217 ppm or mg/L as NaCl at 25ºC
- A1100241 74380 ppm or mg/L as NaCl at 25ºC

Equivalent TDS Standards from IC Controls:
- A1100245 47 ppm or mg/L as NaCl at 25ºC
- A1100246 692 ppm or mg/L as NaCl at 25ºC
- A1100247 7230 ppm or mg/L as NaCl at 25ºC

What to Order, for Drinking Water Taste monitoring and Reverse Osmosis permeate Taste monitoring by TDS

1 TDS analyzer, 210-C(TDS)-1-10-20 Recommended option: TDS Standards
1 TDS sensor, 404-2.0

210-C(TDS): Analyzer

Benefits - Solid metal industrial survivor housing
- Display shows TDS, temperature, 4 alarms, 2 4-20 mA
- Display TDS in units of ppm, mg/L, or ppt
- SCF factor adjustable between 0.40 - 1.10
- Easy calibration - recognizes standards, holds outputs
- Self- and sensor diagnostics
- 4-20 mA outputs: 1 for TDS, 1 for Temperature
- 4-20 mA limits direct set in ppm or mg/L TDS
- Four programmable alarms with self- and sensor alert
- ON-OFF control and/or pump pulser control
- TDS set point units direct set in ppm, mg/L, or ppt
- Optional PID control
- Optional communications

Model 404-2.0: TDS Sensor, conductivity based

Benefits - Rugged CPVC sensor body
- Rugged TDS Sensor with direct connect wiring
- Rapid and accurate TDS readings
- Easy calibration – in air or TDS standards
- Easy in line Standardize – with grab samples
- Temperature to 70°C (158°F) max. at 414 kPa (60psi)
- Pressure to 1.2 MPa (175 psi) max. at 38°C (100°F)
- Signal lead 3 M (10 Ft) included; longer available
- Automatic temperature compensation
- Constructed of titanium, viton and CPVC
- Direct insertion, 1" NPT screw in design
- Low maintenance

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Process Water Analysis Equipment since 1979

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TDS Contaminated Condensate Diversion or Recovery

Recovery of otherwise questionable quality TDS contaminated condensate can be easily and economically handled by a 210-C Analyzer and a 401-0.1 sensor plus a 3 way solenoid valve.

Returning condensate can be (but may not be) contaminated with untreated water from heat exchanger leaks or process liquids and often goes to sewer. Hot condensate at 20 PSIG compared to make up water at 60°F represents a loss of 200 BTU per lb. A 1 gallon per minute hot condensate trickling to sewer cost about $12000.00 in heat loss per year (1 gal/min x 8.33 lb/gal x 60 min x 24 hr x 365 d x 200 BTU/lb) x 14.00/10^6 BTU ($90.00/bbl oil) = approx $12000.00.

Where returning condensate may be contaminated so it goes to sewer, use of a simple condensate monitoring system plus a 3 way diversion solenoid valve can pay for itself in the first year.

What to Order for Contaminated Condensate Diversion

1 TDS analyzer, 210-C(TDS)-1-10-20
1 TDS sensor, 401-0.1

Recommended options: TDS Standards
A9200000 Sensor Signal to Analyzer Cable

210-C(TDS): Analyzer

Benefits - Solid metal industrial survivor housing
- Display shows TDS, temperature, 4 alarms, 2 4-20 mA
- Display as TDS, units available are ppm, mg/l, or ppt
- SCF factor adjustable between 0.40 - 1.10
- Easy calibration - recognizes standards, holds outputs
- Self- and sensor diagnostics
- 4-20 mA outputs: 1 for TDS, 1 for Temperature
- 4-20 mA limits direct set in ppm or mg/L TDS
- Four programmable alarms with self and sensor alert
- ON-OFF control and/or pump pulser control
- TDS set point units direct set in ppm, mg/L, or ppt
- Optional PID control
- Optional communications

Model 401-0.1: TDS Sensor, cond. based

Benefits - Solid metal Boiler House survivor housing
- Rugged TDS Sensor with Explosion Proof Housing
- Rapid and accurate TDS, or non-neutralized TDS
- Easy calibration – in air and TDS Standards
- Easy in line standardize – with grab samples
- Operating temperature to 150°C (302°F) maximum
- Operating pressure to 2.8 MPa (400 psi) maximum
- Automatic temperature compensation
- Constructed of 316 SS, VITON, and PEEK
- Direct insertion, 3/4" NPT screw in design
-Low maintenance

Option 1 **TDS Standards**

Benefits
- Calibrate is easy, no long time delay
- range of values available
- includes table of values at various temperatures

Can be traced to NIST
- A1100244 70.1 ppm or mg/L as NaCl at 25ºC
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Option 2 **A9200000 Cable J-Box to Analyzer**

Benefits
- Manufacturers recommended cable
- shielded sensor signal gets back to analyzer
- protection from stray electrical noise
- reliable sensor and analyzer performance
- wire size fits terminal blocks
- unlike typical 14 Gage solid wire, easily makes turns
- low maintenance
- available by the meter (or foot), specify length desired

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Trade Marks Alka-Seltzer® Bayer; 442® Myron L

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