RCT and RCTW

Purpose

The **RCT** and **RCTW** systems are used to accurately and quickly determine the chloride ion content from powder samples of concrete obtained on-site or in the laboratory using the **Profile Grinder** (see Data Sheet) or other means. The test results can be used for:

- Establishing the chloride ion profile for service life estimation
- Establishing the depth of removal of a chloride ion contaminated surface layer
- Diagnosing a structure for corrosion activity, in combination with other test systems such the **Mini Great Dane**, **GalvaPulse**, and **Rainbow Indicator** (see relevant data sheets)
- Monitoring the chloride ion content during electrochemical removal of chlorides
- Measuring the chloride ion content of fresh concrete or its constituents

Principle

A powder sample of hardened concrete is obtained by drilling or grinding the cover concrete in the structure, or a sample is obtained from the fresh concrete. The sample is mixed with a specific amount of extraction liquid and shaken for 5 minutes. The extraction liquid is designed to neutralize disturbing ions that may interfere the measurements, such as sulfide ions, and extracts the chloride ions in the sample. A calibrated chloride selective electrode is then submerged into the solution to determine the amount of chloride ion, which is expressed as percentage of concrete mass.

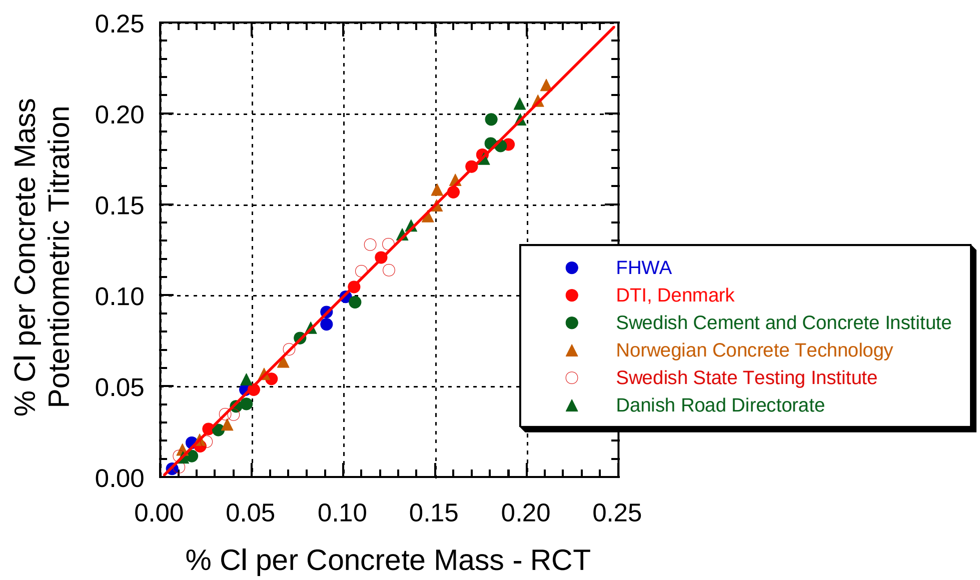
Two extraction methods can be used:

- The **RCT** (**R**apid **C**hloride **T**est) to determine the amount of acid-soluble chlorides
- The **RCTW** (**R**apid **C**hloride **T**est **W**ater) to determine the amount of water-soluble chlorides

The two methods use different kinds of extraction liquids. The type of method to use will depend on the specification criteria for maximum allowable chloride ion content in either hardened or fresh concrete. Note that the acid extraction does not remove chemically bound chlorides.

Accuracy

Numerous correlations have been made between **RCT** test results and chloride ion content determined by standard laboratory potentiometric titration methods such as AASHTO T 260, ASTM C114, EN 14629. The following graph shows the results of such correlations made by various laboratories in the Scandinavian countries and in the U.S.



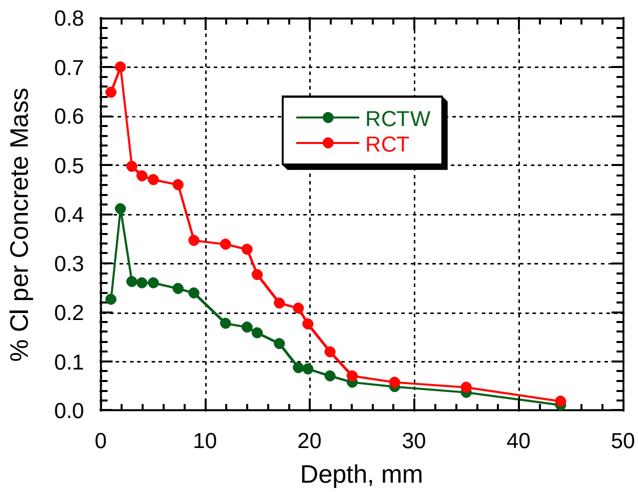
In one comparison whose results are illustrated in the next table, the Swedish National Testing Institute produced concrete powders made with different binders and containing known amounts of chloride ion introduced into the concrete by diffusion. Parallel testing was done in accordance with AASHTO T 260 and with the **RCT** system. The **RCT** readings were taken after the powder samples were kept in the extraction liquid overnight to obtain full extraction of acid-soluble chlorides.

Alternatively, if the result is obtained after 5 minutes of shaking of the vial, a correction factor can be applied to the measured chloride ion content.

Material	% Cl^- per Mass of Concrete		
	Known Amount	AASHTO T 260	**RCT**
Portland Cement (CEM I)	0.023 0.071 0.328	0.024 0.070 0.314	0.022 0.072 0.321
–Fly Ash Cement (CEM II/B-V)	0.020 0.057 0.244	0.019 0.052 0.229	0.019 0.061 0.238
Slag Cement (CEM III/B)	0.020 0.056 0.244	0.019 0.052 0.231	0.019 0.059 0.238

The accuracy of the **RCT** results compared with the known amount of chlorides is as good as with the AASHTO T 260 potentiometric titration method. The average deviation of the **RCT** results from the known amount of chlorides is within ± 4 %.

For repeated testing with the **RCT** on the same concrete powder, the coefficient of variation of test results is on average 5 %. The precision and accuracy of the **RCTW** test for water-soluble chlorides is similar to **RCT** results.



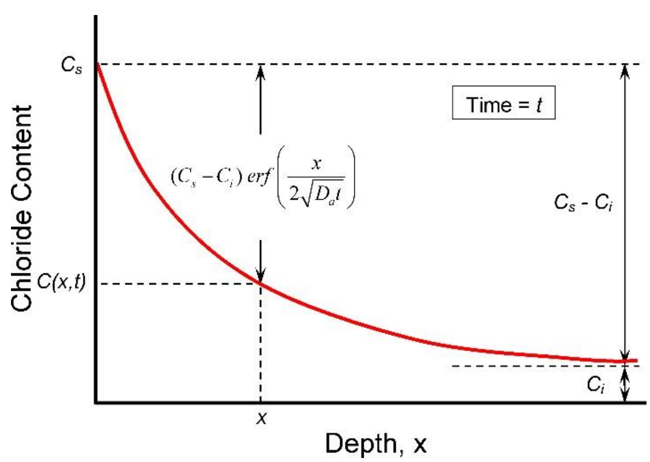
Testing Examples

The graph to the right shows two profiles obtained from on-site profile grinding on a highway bridge column exposed to deicing salts for 4 years. Concrete powder samples were obtained at depth increments of 1 to 2 mm and were analyzed for acid-soluble chlorides with the **RCT** and for water-soluble chlorides with the **RCTW**. A depth of carbonation of 2 mm measured using the **Rainbow Indicator** (see data sheet), corresponding to the initial peaks of the chloride ion profiles obtained.

Data Analysis

For laboratory tests in accordance with ASTM C1556 or NT Build 443, the chloride content profile obtained after a given period of immersion in the specified chloride solution can be subjected to regression analysis to obtain the apparent chloride diffusion coefficient. The testing condition is assumed to result in one-dimensional diffusion and the chloride ion content as a function of depth is assumed to obey the following solution to Fick's second law of diffusion **(1)**:

$$C(x,t) = C_s - (C_s - C_i)\, erf\left(\frac{x}{2\sqrt{D_a t}}\right) \qquad (1)$$



where;

$C(x,t)$ = the chloride ion concentration at a depth x in mm from the exposed surface for an elapsed time t in years since the start of chloride exposure;

C_s = the chloride concentration at the surface, as a % of concrete mass;
C_i = the initial (or background) chloride concentration of the concrete, as a % of concrete mass;
erf = the error function (function related to the integral of the normal probability function); and
D_a = the apparent chloride diffusion coefficient in mm²/year

Eq. (1) describes the variation of chloride ion content as a function of the distance x from the surface after an elapsed time t since initial exposure to a constant surface chloride concentration of C_s. This function is shown as the red curve in the above figure. The values of the equation parameters (C_s, C_i, and D_a) are determined using least-squares curve fitting, which can be implemented using, for example, the "Solver" function in Microsoft Excel or using statistical software that permits general non-linear regression analysis. The value of C_i will be zero (0) if there is no background chloride present initially in the concrete.

The diffusion coefficient in research papers is reported often in units of 10^{-12} m²/s. To convert to units of mm²/y, multiply by 3.15576×10^{13}. For good quality concrete, typical values of the chloride diffusion coefficient are 10 to 100 mm²/y.

Service Life Estimation
If the structure has been exposed to moist conditions so that diffusion has been the primary transport mechanism for chloride ions, a common application of the chloride profile obtained by **RCT** or **RCTW** and the apparent chloride diffusion coefficient given by the best fit regression of Eq. (1) is to determine at what time t, the chloride content at the depth of the reinforcement would reach the chloride ion threshold for initiation of corrosion. This service life time estimation assumes that the surface chloride concentration and diffusion coefficient do not change in the future and the effect of ambient temperature is not considered. Therefore in practice, the chloride profile should be reevaluated at reasonable regular intervals in order to update the expected service life of the structure.

Chloride Ion Threshold
There is no a single unique value for the amount of chloride ions in concrete that will breakdown the protective oxide film and initiate corrosion of steel reinforcement. The value depends on many variables, among others, the exposure conditions, the water-cementitious materials ratio, the types of cementitious materials in the concrete, etc. For estimating the chloride ion threshold, a model given by **Eq. (2)** and **Eq. (3)** has been proposed **(1,2,3)**:

$$C_{cr} = ke^{-1.5(W/C)_e} \quad (2)$$

$$(W/C)_e = \frac{W}{C - 1.4 \times FA - 4.7 \times SF} \quad (3)$$

where;

C_{cr} = Chloride threshold percent by mass of binders

$(W/C)_e$ = Equivalent w/cm ratio (W = water, C = cement, FA = fly ash, SF = silica fume)

k = 1.25 for marine exposure and splash zone

k = 3.35 for submerged exposure in seawater

RCT-500 Kit

RCT Electrometer and Electrode Specifications

- Input Impedance: 1,012 Ohm
- Battery Type / Life: 1 x 9V / approx. 150 hours
- Auto-off after 20 minutes of non-use
- Environment: 0 to 50°C; RH max 95%
- Temperature and pH measuring capacity (pH electrode and temperature probe are sold separately)
- Range: ±1,999 mV
- Resolution: 0.1 mV for ±700 mV and 1 mV for ±2,000 mV
- Accuracy: ±0.2 mV for ±700 mV and ±1 mV for ±2,000 mV
- Electrode type: Combination chloride ion selective electrode with waterproof BNC connection

RCT-500 Kit Ordering Numbers

Item	Order #
RCT chloride selective electrode	RCT-770
Electrometer for mV, pH and ºC	RCT-990
Electrode wetting agent, 80 mL, with spout	RCT-1000
Distilled water, spray bottle	RCT-1001
Polishing strips for electrode	RCT-1002
Plastic bags for powder sampling	RCT-1003
Powder collecting bowl	RCT-1004
Powder collecting pan, circular	RCT-1005
Powder collecting square w. clip	RCT-1006
Adjustable pliers	RCT-1007
Set of anchoring tools	RCT-1008
Mandrel	RCT-1009
Hammer	RCT-1010
Powder compression pin	RCT-1011
Powder weighing ampoules, 6 pcs	RCT-1012
Digital pocket balance, 115 x 0.01 g	RCT-2700

Item	Order #
Calibration liquid, 0.005 % Cl^-	RCT-1013
Calibration liquid, 0.020 % Cl^-	RCT-1014
Calibration liquid, 0.050 % Cl^-	RCT-1015
Calibration liquid, 0.500 % Cl^-	RCT-1016
Cleaning tissues	RCT-1017
Calibration sheets for hardened concrete	RCT-1018
Calibration sheets for fresh concrete	RCT-1019
Rubber ball dust remover	RCT-1020
Pencil and ruler	RCT-1021
Measuring tape	RCT-1022
Extraction vials, hardened concrete, 10 pcs	RCT-1023
Manual	RCT-1024
RCT testing cases and applications, binder	RCT-1025
Attaché case	RCT-1026

The **RCT-1025** binder contains 20 years of testing experience, including theory and applications for chloride diffusion modeling.

It is recommended to always have an extra set of clean **RCT-1030** calibration liquids to ensure that the chloride electrode is working properly if deviations occur from the usual obtained calibration curve.

Extra Parts

RCT-1030 *set of calibration liquids, 0.005, 0.020, 0.05 & 0.5 % Cl^-*

RCT -1032 *mixing container and cup. For samples of fresh concrete*

RCT -1000-1 *electrode wetting agent (EWA), 300 mL. For refilling the RCT-1000 bottle with spout*

Consumables

Extraction liquids for **RCT** testing for acid-soluble chlorides in hardened concrete or fresh concrete:

RCT-1023 *vials,*
set of 25, for testing hardened concrete

RCT--1031 *vials,*
set of 4, for testing fresh concrete

Extraction liquids for **RCTW** testing for water-soluble chlorides in hardened concrete or fresh concrete:

RCTW-1023-1 *vials, set of 25,*
RCTW-1023-2 *buffer vials, set of 25,*
for testing hardened concrete

RCTW-1031-1 *vials, set of 4,*
RCTW-1031-2 *buffer vials,*
set of 4, for testing fresh concrete

Optional items

RCT-1027 *Certified Reference Powders*
9 jars, each containing 70 grams of concrete powder, with known amounts of chlorides and titrated according to AASHTO T 260

Cement type*	**Known amounts of Cl⁻**		
Portland cement	0.023 %	0.071 %	0.328 %
Fly ash cement	0.020 %	0.057 %	0.244 %
Slag cement	0.020 %	0.056 %	0.244 %

*According to ENV- 197-1

RCT-1028 *pH-electrode*

- Range: 0.0 to 12.0 pH
- Temperature: -5.0 to 70.0°C
- Meter resolution: 0.01 pH
- Meter accuracy: ±0.01 pH

RCT-1029 *temperature probe*

- Range: -20.0 to 120.0°C / -4.0 to 248.0°F
- Meter resolution: 0.1°C / 0.1°F
- Meter accuracy: ±0.4°C / ±0.8°F

References

(1) Poulsen, E. and Mejlbro.L., **Diffusion of Chlorides in Concrete, Theory and Application**, Modern Concrete Technology Series, Taylor and Francis, 2006, ISBN13: 9-78-0-419-25300-6

(2) Nilsson, L.O., Sandberg, P., Poulsen, E., Tang, L.M. Andersen, A. and Frederiksen, J.M., "A System for Estimation of Chloride Ingress into Concrete: Theoretical Background," HETEK Report 83, 1997, http://www.hetek.teknologisk.dk/english/16507

(3) Frederiksen, J.M. and Poulsen, E. "Chloride penetration into concrete—Manual," HETEK Report 123, 1997, http://www.hetek.teknologisk.dk/english/16507