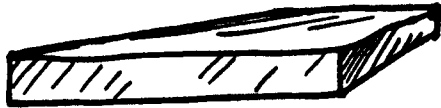


CORROSION MEASUREMENT

If a piece of metal



corrodes to this



how would we know how much corrosion had occurred?

Clearly, we need “before” and “after” measurements, but of what?

SIZE?

Length, breadth and thickness before

- what about after?

Volume before, volume after; for example by liquid displacement

- sensitive enough ?

MASS?

Weigh before, weigh after (if piece small enough for reasonable balance; note that measuring weight losses to a fraction of a mg in a few mg is the norm in corrosion testing).

To be of any use, a weight loss measurement has to be scaled to the size of the specimen; because corrosion is a surface phenomenon, weight loss is related to surface area (SA).

EXAMPLE:

a metal “coupon” having a total surface area of 10 cm² loses 1 mg when exposed to a particular environment for a month;

$$\text{total corrosion} = \frac{1}{10} \frac{\text{mg}}{\text{cm}^2}$$

which should be a characteristic amount for that metal in that environment in a month.

$$\text{i.e., the rate} = 0.1 \frac{\text{mg}}{\text{cm}^2 - \text{month}}$$

Corrosion engineers usually work in terms of dm², so our rate becomes:

$$0.1 * 100 = 10 \frac{\text{mg}}{\text{dm}^2 - \text{month}} = 10 \text{ “mdm”}$$

BUT even though “mdms” give reasonable numbers for most corrosion situations, the month is a bad unit why?

The unit most often used is: $\frac{\text{mg}}{\text{dm}^2 \text{ day}}$ i.e. "mdd"

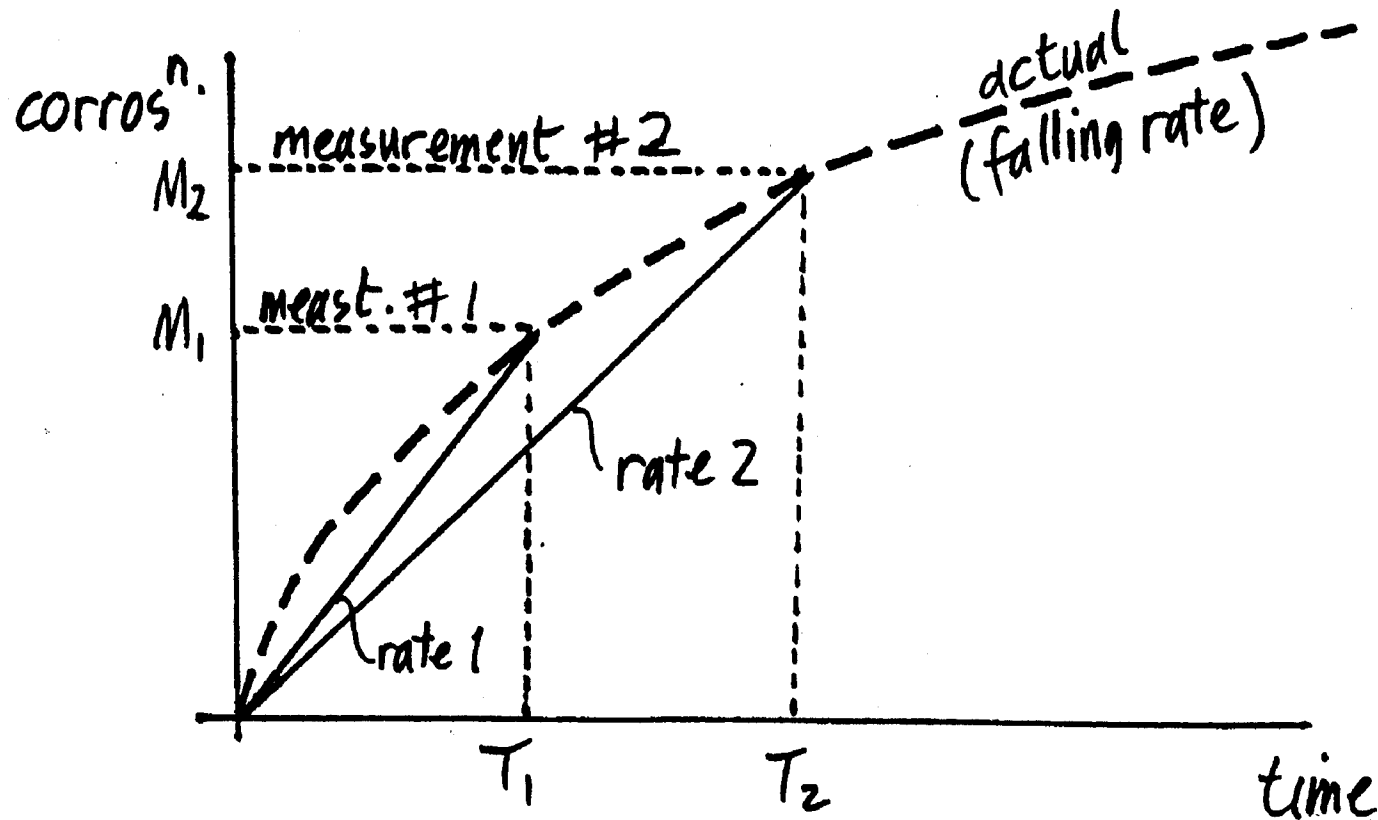
If we know the metal density, then we can convert weight loss to "penetration"
for ρ in g/cm^3

$$\begin{aligned} \times \frac{\text{mg}}{\text{dm}^2 \text{ day}} &\equiv 0.1 \frac{\text{x}}{\rho} \frac{\mu\text{m}}{\text{day}} \\ &= 36.5 \frac{\text{x}}{\rho} \frac{\mu\text{m}}{\text{year}} \end{aligned}$$

AND

$$Z \frac{\text{mm}}{\text{year}} = \frac{Z}{25.4} \frac{\text{mil}}{\text{year}} \quad (\text{mil} = 10^{-3} \text{ inches})$$

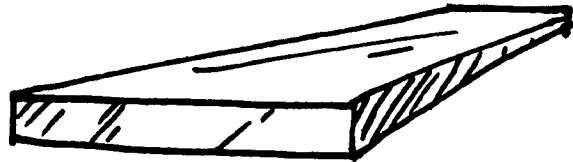
NOTE: these rates are averaged over the exposure time, and are quoted as if corrosion were constant with time; it often isn't.



measured rate 1 = $\frac{M_1}{T_1}$

measured rate 2 = $\frac{M_2}{T_2}$

Often, our bit of metal...



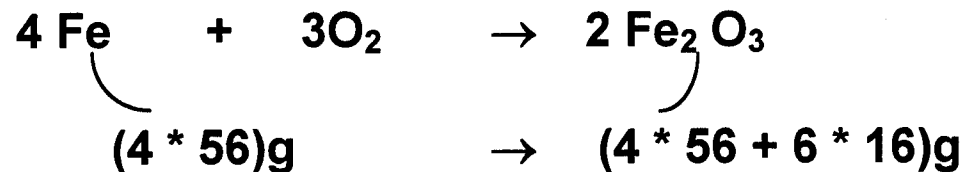
after exposure, looks like this....



i.e., it is covered with scale .

How would we assess corrosion under these conditions?

Scaled (e.g., oxidized) specimens often experience a weight gain.....
thus, the high-temperature oxidation of iron proceeds.....



If we know scale composition (e.g., type of oxide) and weight gain, we can calculate the Fe in the oxide and, therefore, the Fe corroded.

BUT we can account exactly for the corrosion... some might fall off (“spall”)
some might have been deposited from the environment

CONSIDER THE SCALING PROCESS.

weight before = W_0 g

surface area = A dm^2

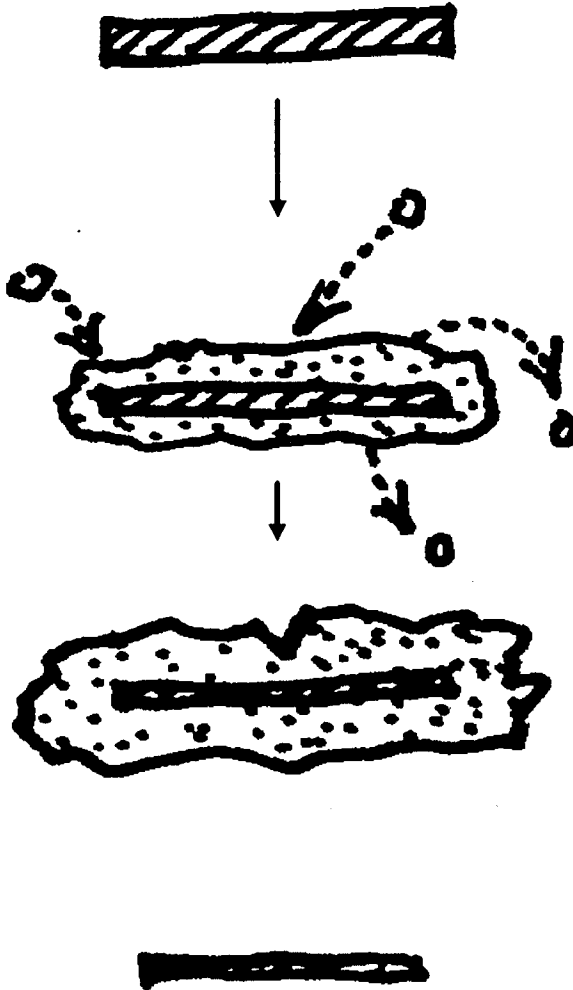
exposure.. time = θ day

final condition: weight after = W_1 g

we can only be sure that the remaining metal provides an unequivocal reference, so....

descale ↓

descaled weight = W_2 g



Corrosion can be calculated as:

$$\text{total corrosion} = \frac{1000 (W_0 - W_2)}{A} \frac{\text{mg}}{\text{dm}^2} \quad (\text{divide by } \theta \text{ for rate in mdd})$$

We also have a measure of the scale:

$$\text{scale} = \frac{(W_1 - W_2)}{A} \frac{\text{g}}{\text{dm}^2}$$

If we assume scale = Fe_2O_3 , iron in scale is given by:

$$\text{Fe} = \frac{(W_1 - W_2)}{A} \frac{\text{mg}}{\text{dm}^2}$$

difference between Fe in scale and total corrosion is either:

- Fe released to environment or
- Fe deposited from environment.

HOW TO DESCALE?

Chemically or electrochemically, usually in weak acids.

BUT.. such descaling can also dissolve some of the remaining metal, so...

- employ an “inhibitor” (more about this later)
- use a “blank”

a blank is a “bare” specimen put into the descaling solution along with the specimen; if the blank corrodes by

$$1000 \frac{\Delta W_b}{A_b} \frac{\text{mg}}{\text{dm}^2}$$

during the descaling, we apply this “blank correction” to the specimen measurement

NOTE: Such corrosion measurements and units are useful for “general” or “uniform” corrosion.

They don’t work for “localized” corrosion (e.g., pitting or cracking). A component can fail by “stress corrosion cracking” (SCC) with no detectable weight loss.



Use concepts of “crack propagation” or “pit propagation” (e.g., “percent through-wall” for tubes, pipes, vessels, etc.; “crack depth” or “pith depth” usually μm or mm ; “propagation rate” in $\mu\text{m}/\text{year}$, mm/year , etc.)

“Localized” Corrosion



Stress corrosion of type 304 (stainless steel) autoclave. (Mallinckrodt Chemical Works)

components (e.g., a pressure vessel)?

Methods involve:

- **Non-Destructive Evaluation (NDE)**
- **Non-Destructive Testing (NDT)**

These include:

- **Ultrasonic Testing (UT);**
- **Eddy Current;**
- **Acoustic Emission;**
etc.