Can levels of suspended & settled solids build up in a Closed System following a Pre Commission Cleaning?

There are a number of process which can contribute to the creation of suspended & settled solids in a closed system following complete and successful Pre-Commission Cleaning (PCC) e.g.:

a) Precipitation of Calcium Carbonate due to temperature & pH rise and liberation of dissolved CO_2
b) Metals (predominately iron) dissolved/corroded from pipe even in a well inhibited closed system
c) Microbiological causes

Treatment processes are designed to inhibit and control corrosion they are unlikely to prevent it entirely.

EXAMPLE:

System description:

Closed condenser water circuit (~40°C) with 4 x 2500Kw evaporative condensers (stainless steel coils) on the roof and 4 x 1500Kw chillers & associated St/St Plate Heat Exchangers in basement.

Associated steel pipework consisting of 300mmΦ diameter risers (140m) and 250mmΦ distribution pipework (40m)

System water volume: Note all following measurements are in meters ($\prod r^2L$)
Risers:
$3.142 \times 0.15 \times 0.15 \times 140 = 9.89m^3$
Distribution:
$3.142 \times 0.125 \times 0.125 \times 40 = 1.96m^3$
Heat exchangers:
$8 \times 0.4 = 3.2m^3$
Total water volume = $9.89 + 1.96 + 3.2 = 15.05m^3$

Surface area of steel pipework: ($\prod DL$)
Risers:
$3.142 \times 0.3 \times 140 = 131.96m^2$
Distribution:
$3.142 \times 0.25 \times 40 = 31.42m^2$
Total surface area of steel pipe = $131.96 + 31.42 = 163.38m^2$ ($1,633,800cm^2$)

Volume of iron that could be dissolved (corroded) from steel pipework in a year?

Buildcert/NSF/CIA require corrosion inhibitors to achieve an overall penetration of 0.04mm (0.004cm)/year or better for mild steel.
At this overall penetration rate we could dissolve (corrode) the following volume of iron/steel:
Surface area of pipework cm^2 x penetration cm = cm^3 iron/steel dissolved
$1,633,800 \times 0.004 = 6,535cm^3$/year

Weight of steel dissolved/corroded in a year:

Volume dissolved cm^3 x density g/cm^3 *(Density of mild steel = 7.86g/cm³)*
$6,535 \times 7.86 = 51,365.1g$ (51.3651Kg)

Where does this dissolved/corroded steel go?

Dependent on various factors, e.g. pH, temperature, dissolved O_2 it will probably become a mixture of precipitated Ferrous and Ferric hydroxides & oxides. For the sake of this calculation, we will assume it all precipitates as Ferrous Hydroxide $Fe(OH)_2$.

In this case 51.365Kg of iron will produce 82.54Kg of dry weight Ferrous Hydroxide $Fe(OH)_2$.

If this all stays mobile and does not settle as sludge or adhere to pipe walls then the circulating suspended solids level will be:

82.54Kg/15.05m^3 = 5.484Kg/m^3 (5,484ppm)

This is unlikely to be the case as the suspended Ferrous Hydroxide could produce settled solids in low flow areas or be removed by filtration, dirt collectors etc. So how much settled sludge could be produced?

Gravity Settled metal hydroxides are usually approximately 5% dry weight (see extract below) so 82.54Kg Ferrous Hydroxide would produce approx. 82.54 x 100/5 = 1,651 litres of sludge.

Even If the overall corrosion rate was reduced considerably to say 0.01mm/year the system could still produce a considerable volume of settled sludge e.g.

1,651/4 = 412 litres/year (34litres/month)

In a period of 3 months from PCC to PC the system could produce 100 – 400 litres settled Ferrous Hydroxide sludge, even with good corrosion inhibition.

Calcium Carbonate Precipitation.

As this system does not contain aluminium it is being operated at pH above 9.5 in which case additional suspended solids & sludge could have been produced following filling due to precipitation of Calcium Carbonate. This could have produced a further approximately 45 liters of settled sludge.

The outcome is that it is possible to generate enough sludge/settled solids to fill a few terminal units within a short time after complete and successful Pre-Commission Cleaning.

Is it possible to calculate the potential sludge/settled solids that could form?

Every system will be different however knowing the surface area of specific metal components and the accurate corrosion rates it is possible to calculate the amount of metal oxide/hydroxide that could be precipitated. In addition, knowing the Calcium content of the fill and system water, operating temperature & pH and the volume of the system, etc. it is possible to calculate the amount of Calcium Carbonate precipitated.

There are number of other factors that could impact on the volume of sludge circulating and or settling post PCC e.g.

Is the measured corrosion rate accurate?
Impact of passivation or not?
Reduction of inhibition by flushing/water change post PCC
Irregular circulation
Presence of: Filters, Dirt pockets, their size and how often they are changed & emptied.
Post PCC management & operation, etc.

It is not inevitable that significant debris/sludge accumulation will occur and countless systems are monitored from PCC up to and beyond PC with solids kept within the guidelines in BSRIA/CSCA BG29 up to PC and often for a long time after. In fact many systems are still essentially clean several years after PC as a result of a good standard of preparation by effective pre-commission cleaning and good maintenance thereafter.

However it is possible that a system could become fouled even in a few months following a thorough PCC. This fouling may not be because the PCC was inadequate, it could be due to the processes described above. Each case must be evaluated before making judgements.

EXTRACT: Treatment of Metal-Bearing Effluents: Removal and Recovery
Ghinwa M. Naja and Bohumil Volesky

9.1.1.5 Sludge Thickening

The flocculation/clarification stage is usually followed by the sludge-thickening stage. A sludge thickener is typically a conical bottom tank that receives the underflow from the clarifier and provides storage where further **gravity settling of solids can take place. The sludge concentrated at the bottom of the tank contains about 4–6% solids**.

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