

QUESTIONS

AND ANSWERS

Phosphate Hideout

What is phosphate hideout?

Phosphate hideout is a phenomenon that causes boiler water control difficulties. It is defined as the disappearance, by precipitation or absorption, of the ionic phosphate (PO_4) species, in the boiler water under high heat transfer or high load conditions.

When the high heat flux or high load condition is reduced, the species (phosphate) returns from hideout, creating even more control difficulties. The magnitude of phosphate hideout and the variation in load required to cause the phenomenon vary from one boiler to another.

Phosphate hideout is primarily a result of a temperature-dependent interaction of sodium phosphate compounds with iron oxide, which creates a low solubility reaction product that precipitates in high heat flux areas or under high load conditions. At lower loads and lower heat fluxes, the precipitates return to solution.

How do I recognize it?

Phosphate hideout becomes evident in load swings or start-ups with changing heat input. As the load is increased, the pH increases with the decreasing phosphate. When the load is reduced, the pH decreases and the phosphate increases, without chemical additions to the boiler.

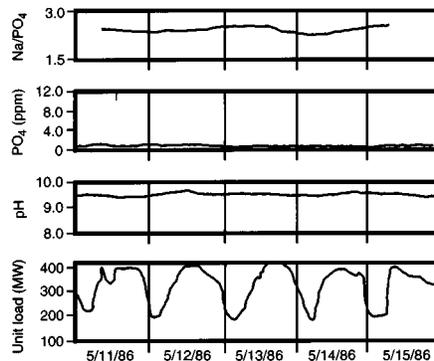


Figure 1 — Normal congruent phosphate-pH boiler chemistry.

During phosphate hideout, little or no change in phosphate and/or pH values occurs when chemical charges are added to the system since fresh phosphate may precipitate along with that which has already occurred. The readings for pH and phosphate are typically out of control during hideout when the load is increased, and then again when it is decreased.

While it seems that the phosphate has mysteriously disappeared, and that additional charges are unsuccessful in increasing the phosphate reading, the actual phosphate inventory in the boiler has not decreased. It has combined with oxide deposits to form a slightly lower Na/ PO_4 ratio solid (approximately 2.1:1), causing an increase in alkalinity in the liquid phase (bulk water) — hence the boiler water pH increases. When the load is decreased again, these combinations return to the soluble form and the phosphate returns to the bulk water, causing higher phosphate readings and lowered pH.

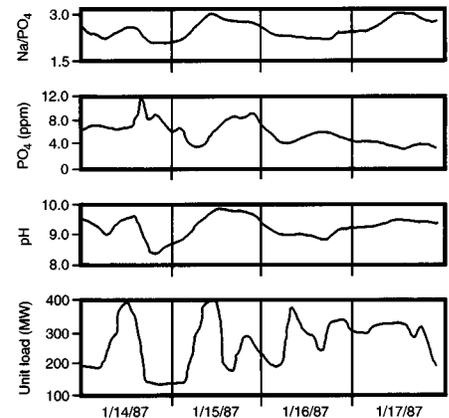


Figure 2 — Phosphate hideout caused by lower combustion zone.

The best way to recognize phosphate hideout is to graph load changes, pH, and phosphate over a period of time. The variations of the graphs will clearly indicate that the phosphate increases with decreasing load, and that the pH decreases with decreasing load (see Figures 1 and 2).

Load	pH	Phosphate
Increasing	Increases	Decreases
Decreasing	Decreases	Increases

What causes phosphate hideout?

Events which may lead to phosphate hideout include:

- Start-up after a chemical cleaning
- Changes in unit load
- Changes in burner configuration
- Metal oxide ingress and deposition on heat transfer surfaces

Does the hideout vary?

Each boiler, due to design and cleanliness factors, will exhibit somewhat different magnitudes of hideout. The cleaner the boiler, the less likely hideout will be for operating units. For units that have just been cleaned, the hideout phenomenon may temporarily appear severe as phosphate is consumed to re-establish the equilibrium between the boiler water and the iron oxide or heat transfer surfaces, since phosphate-based passivation solutions are not typically used for post-cleaning passivation.

How do I treat it?

To treat phosphate hideout effectively, you must first recognize it. The situation will be greatly increased if there is not consistent recordkeeping and graphing being done. Once the phosphate hideout is recognized, treatment steps may be implemented.

The impulsive reaction to hideout is to add more phosphate to try to correct the low readings. This is inadvisable, however, since adding more chemical will only worsen the situation when the load is reduced (see Figure 3).

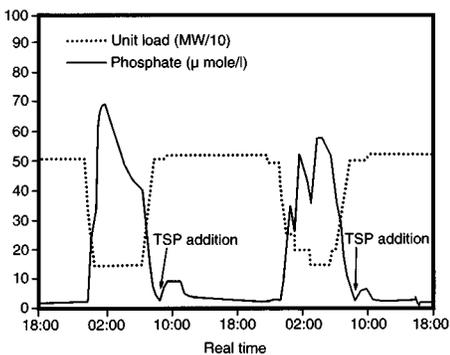


Figure 3 — Changes in concentrations of phosphate with load in unit that is experiencing chemical hideout.

Recently, a utility boiler experienced severe furnace tube corrosion on the hot side of the tubes. The corrosion was transgranular in nature and quite extensive. Along the corroded areas, large quantities of sodium iron phosphate were found, indicating that sodium phosphate from the boiler water had participated in the corrosion mechanism.

Acidic forms of phosphate should not be used in an attempt to increase the phosphate reading. The most acidic form of phosphate is monosodium phosphate.

During start-ups, use mainly trisodium phosphate.

Do not go to heavy blowdown. This will further reduce the sodium:phosphate ratio. It will also make the condition which causes the hideout to worsen by allowing acidic conditions to occur.

Keep the phosphate at the lowest end of the allowable range. This will vary from boiler to boiler and may have to be determined over a period of time.

Since this equilibrium level of phosphate might be quite low, <1 ppm for a high pressure boiler, be alert for conditions that may indicate a condenser tube leak. High sodium, silica, and cation conductivity are all indicators of a condenser tube leak.

What are the consequences of phosphate hideout?

Phosphate hideout causes confusion, frustration over uncontrollable water chemistry, and corrosion. Some phosphate-related corrosion may be severe.

The frustration resulting from uncontrollable water chemistry may be quite high. As lab technicians try to maintain the Na/PO₄ ratio while hideout occurs, the resultant situation is often non-productive. Significant amounts of time and money may be spent to try to regain control. Those whose phosphate hideout problems are severe will undoubtedly be out of control more than they are in control as the unit cycles. Adding more phosphate to the boiler only makes the problem worse. The frustration of being out of control, wondering if corrosion is occurring, and choosing the best solution can be very irritating and lead to expensive mistakes.

The consequences of corrosion, frustration, and confusion lead to one final conclusion: phosphate hideout costs money.

How do I prevent hideout?

Based on work done by J. Stodola of Ontario Hydro, equilibrium phosphate treatment is recommended for units experiencing phosphate hideout to alleviate corrosion risks and to reduce boiler cleaning requirements.

As Figures 4, 5, 6 and 7 depict, reducing the phosphate level in the boiler water greatly reduces variability with load changes, and may eliminate the hideout phenomenon in many boilers.

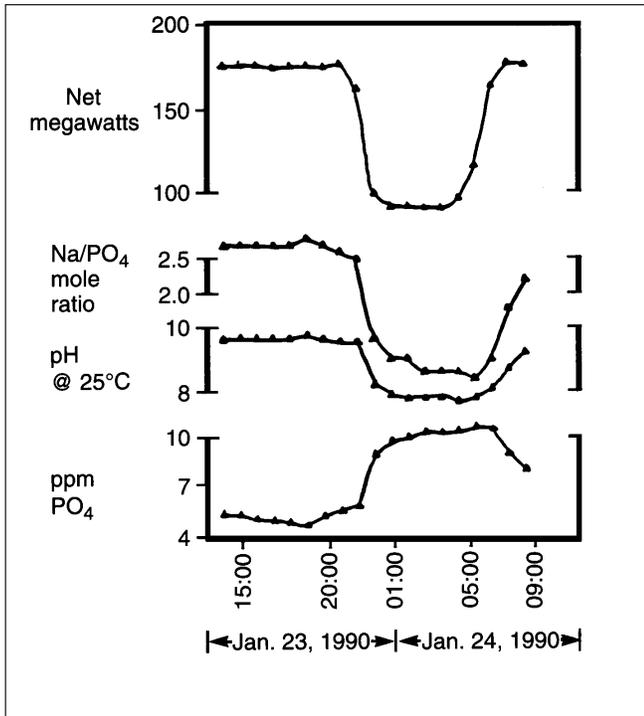


Figure 4 — 5.0 ppm PO_4 @ approximately full load.

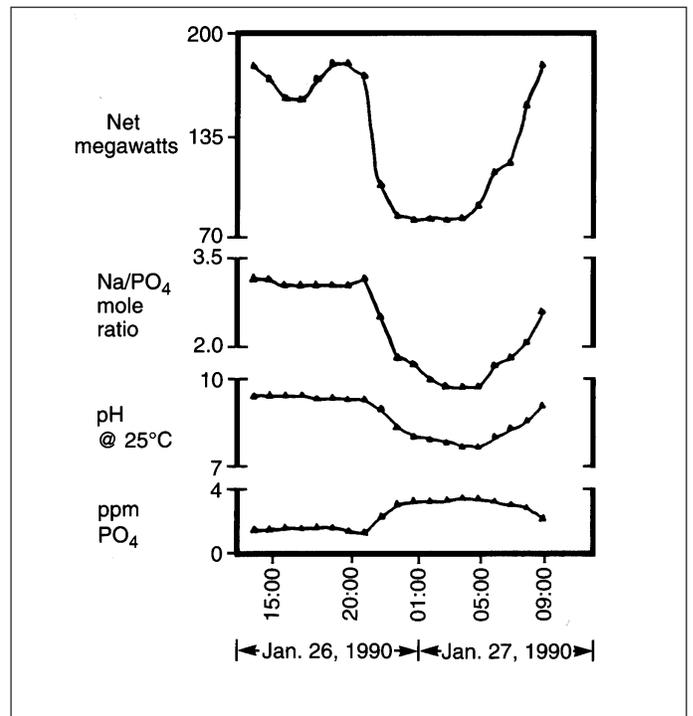


Figure 6 — 1.5 ppm PO_4 @ approximately full load.

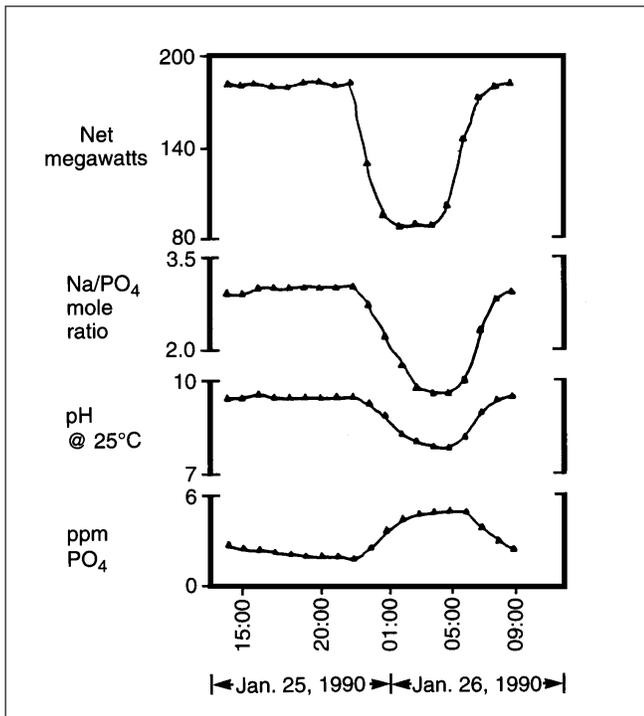


Figure 5 — 1.8 ppm PO_4 @ approximately full load.

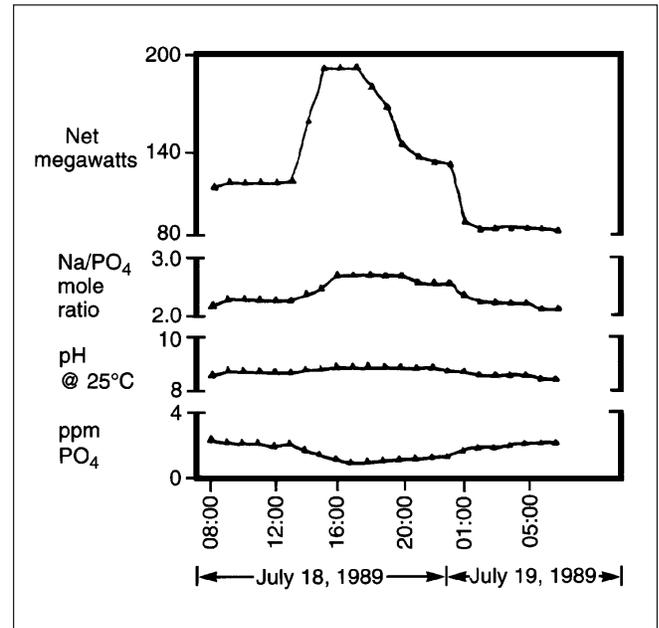


Figure 7 — 1.1 ppm PO_4 @ approximately full load.

Since phosphate hideout is a phenomenon associated with precipitation of phosphate/metal solids in areas of deposits on heat transfer surfaces, it follows that adequate oxygen control and passivation of metal surfaces is important in the prevention of phosphate hideout. Oxygen control efforts must be maintained for many reasons, but in the case of hideout, it is important to control oxygen in the condensate system so that corrosion products are not deposited in the boiler. The deposits can then interact with phosphate during high heat flux conditions to form sodium iron phosphates.

In units where phosphate hideout led to corrosion damage, Stodola notes that removing the minimum phosphate concentration limit and allowing 1 to 2 ppm free caustic alkalinity prevented further corrosion. Table 1 shows equilibrium treatment control limits (at 2600 psig [179 barg]).

Table 1 — Equilibrium phosphate treatment chemistry control limits* at 2600 psig [179 barg]

Parameter	Control Limit
pH	9.0–9.6
PO ₄ (ppb)	0–2400
Cation Conductivity (μS/cm)	≤6.0
Cl (ppb)	≤300
SO ₄ (ppb)	≤300
Silica (ppb)	≤160
<i>*Pressure dependent</i>	

Phosphate hideout in high pressure boilers can be recognized, and prevented by changing to an equilibrium phosphate treatment program. The savings will be seen in reduced operator frustration and a cleaner, less corroded boiler.

Figures 1 and 2, Table 1 — ©1991. Electric Power Research Institute. EPRI TR-100195. Proceedings: International Conference on Fossil Plant Cycle Chemistry. Reprinted with permission by EPRI and J. Stodola, Ontario Hydro, Toronto, Ontario, Canada.

Figure 3 — Originally presented at the 47th Annual International Water Conference, October 27–29, 1986, Pittsburgh, PA. Reprinted with permission by Engineers' Society of Western Pennsylvania and J. Stodola.

Figures 4–7 — Reprinted with permission by American Power Conference, from 1991 Proceedings.