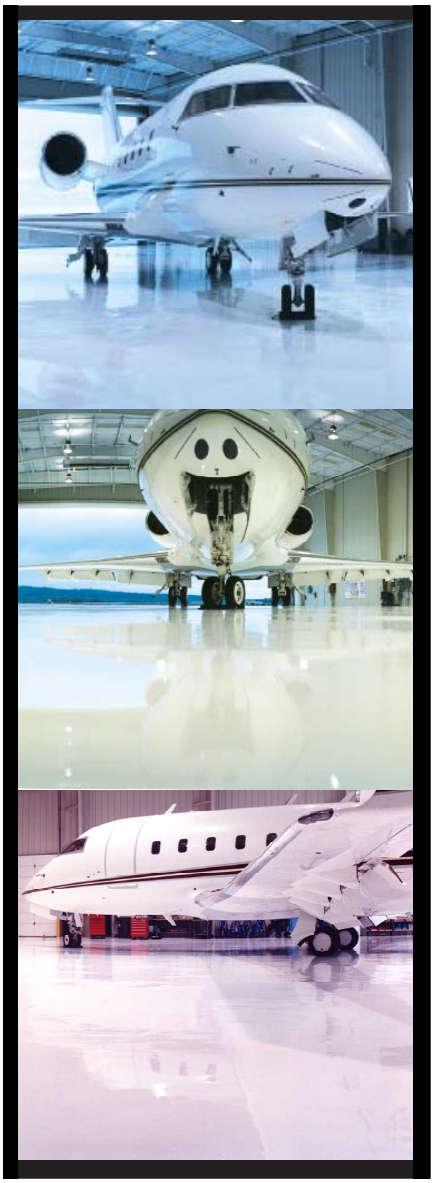
REDFORD Corporation

Having a discussion...
Hydrostatic Pressure ("Bubbles/Blisters")

Draft 06/2006

Dealing with problems caused by excessive hydrostatic pressure in concrete floors is no easy task. The situation is upsetting for both facility owners and flooring installation contractors/coating suppliers. A natural tendency is to finger-point to affix blame, but this energy is better spent searching for a solution to the problem.



The Cause

Hydrostatic pressure problems ("bubbles/blisters") can be encountered anywhere, but some areas of the country are more prone to these problems than other areas.

Specifically, structures located in the Gulf Coast states of Florida, Louisiana and Texas are much more likely to develop problems, because the water table is so close to the ground surface. Buildings and homes in these areas are built without basements because it is nearly impossible to keep subsurface water from entering (and slabs built on grade need to be placed on a properly engineered vapor barrier).

One source of hydrostatic problems is the inherent characteristics of concrete.

First, concrete is permeable, which allows water to migrate through interconnected pore spaces in the cement matrix. The amount of permeability is partly dependent on the water content of the concrete mix when the concrete is placed. A low water content mix results in thicker, stronger and less permeable concrete. However, a mix that is too thick will not flow properly, resulting in air pockets in the concrete. These large pores decrease the strength of the concrete and can permit easier movement of water and contaminants through the concrete.

Secondly, concrete is highly alkaline, sometimes as high as pH13, making the components reactive with even mildly acidic compounds. In addition, some aggregates used in the concrete mix can react with cement alkalis, forming compounds that can swell and cause stress cracks in the concrete. After construction, stress cracks can also form due to movement of the building. Any crack can serve as a pathway for water and contaminants.

One source of problem is the inherent characteristics of concrete.

Coatings are applied to improve the looks of exposed concrete surfaces and to protect the concrete from outside agents. Before coating a surface, cracks and flaws should be repaired because each flaw can contribute to coating failure as well as decrease the structural integrity of the concrete.

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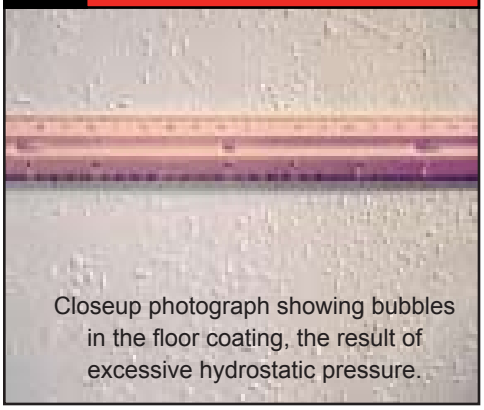
"BUBBLES"



Closeup photograph showing bubbles in the floor coating, the result of excessive hydrostatic pressure.

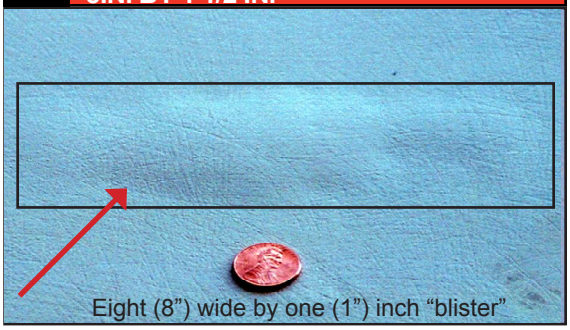
The Manifestation

When water migrates through concrete, either through its molecular permeability, via physical cracks or other imperfections in the concrete, the force of the water can cause small bubbles to form in the coating. When popped, these bubbles will emit pressurized water/ chemical mixtures. Accordingly, when the hydrostatic pressure of water in the concrete exceeds the ability of the coating to adhere to the substrate, the bubbles spread laterally then combine, and eventually the coating will delaminate.

Some types of coatings fare better than others in their ability to resist hydrostatic forces. Epoxy coatings are somewhat more permeable than urethanes, which helps to relieve some of stress. While on the other hand, enamels fare even better than epoxies over the force of hydrostatic pressure but tend to delaminate due to reaction with cement alkalis (saponification). **No coating sticks to concrete so well that it is able to resist excessive hydrostatic forces.**

No coating adheres to concrete so well that it is able to resist powerful hydrostatc forces.

A LARGE "BLISTER"/APPROX. 8IN. BY 1 1/2 IN.



Eight (8") wide by one (1") inch "blister"

concrete at the time of construction, it is sometimes possible to excavate around completed construction to install an appropriate barrier.

At a location with excessive hydrostatic pressure problems and no positive-side barrier, there is no coating that can overcome the force of the water.

Hydrostatic pressure problems are the "Achilles' Heel" of flooring contractors and coating suppliers, which is why they go to great lengths to provide disclaimers, both early in discussions and in writing, to forewarn about this potential problem.

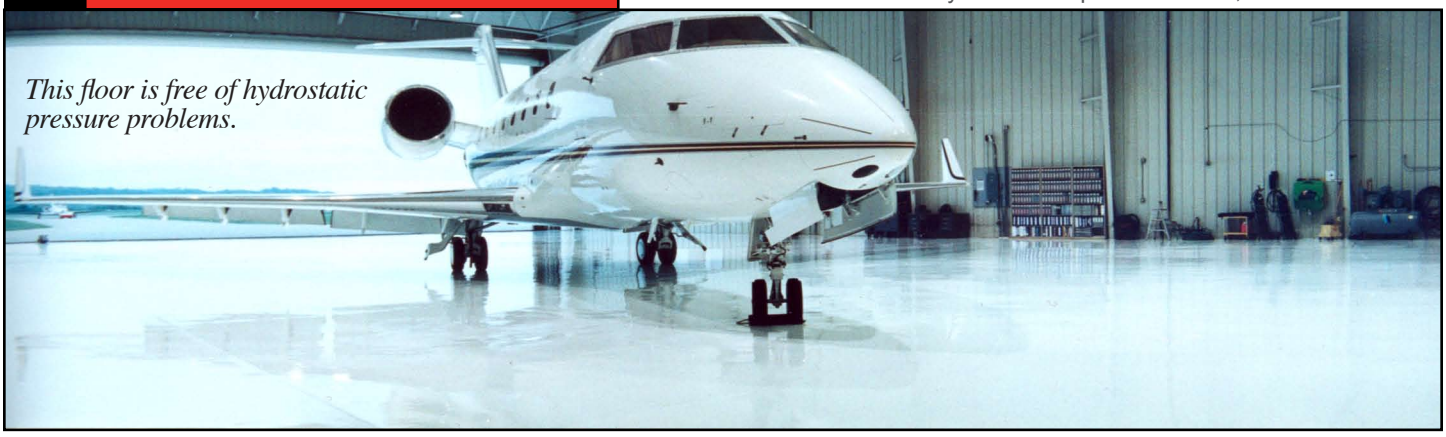
Accordingly, contractors who offer warranties for a 100% successful coating installation do so at there own peril.

New Problems

(A footnote/update: 3rd quarter 2005)

Because of the recent heat wave and excessive moisture experienced in many parts of the country in the 3rd quarter of 2005, we have more than the usual number of hangars with "bubbles/blisters". An analysis involving many factors almost always points back to temperature, but may also involve, importantly, the amount of rain. There may be other factors involved as well. For example, if the concrete was originally poured over standing water/snow/ice, this is an early-on factor that will never go away.

NO "BUBBLES"



This floor is free of hydrostatic pressure problems.

The Prevention/ Correction/Cure

In problem-prone areas, the internal force of the water can easily exceed the strength of the coating to adhere to the concrete. The only effective method to prevent these problems is to stop the flow of water through the concrete. This is done by installation of a positive-side water barrier (a waterproof barrier between the concrete and the source of the water). While it is best to install a waterproof membrane below the

Urethane coatings cannot be applied over concrete (without the risk of bubbles/blisters occurring)!

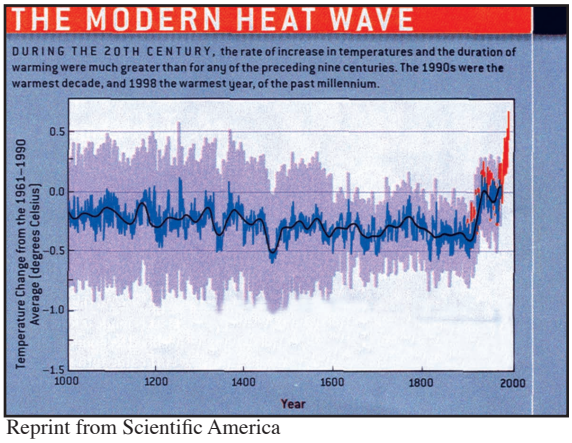
To explain in simple terms what this means in regard to "blisters/ bubbles," consider the following:

Because of the inherently good properties of highly cross-linked, dense urethane coatings (which produce good chemical resistance, long-term gloss, abrasion resistance, etc) moisture (when expanded by heat) can not escape and "pushes up" forming "bubbles/blisters" below the impermeable urethane. There is no remedy that provides a 100% solution to this occurring problem since all concrete has latent moisture and vapors in the concrete that are always trying to migrate out.

Urethane coatings cannot be applied over concrete without the risk of "bubbles/blisters" occurring. **No** matter what product is selected, what contractor is chosen, or whatever amount of money is paid; <u>because</u> the highly cross-linked, dense urethane coating is impermeable to moisture/ vapors escaping. Some hanger floors have coatings with enough tensile strength/adhesion to overcome the forces of gases expanding and trying to escape from the concrete, but other hangar floors do not.

Coating concrete goes agaist all "laws of Physics".

This is further complicated by concrete mixtures, additives present, surface preparation, geographic location, time of year coated, water table, and a multitude of additional factors, all beyond absolute control of the applicator/coating suppler. This does not even take into consideration the constant improvements, better crosslinking of newer of polyols/isocyanates used by the coating suppliers (producing better stain/ chemical resistance, better abrasion resistance, better gloss and color retention etc. (all properties that hanger floor owners expect!). Importantly, new volatile organic content (VOC) limits mandated by states, reduce solvent emissions, but make the current generation of urethane coatings also less permeable, thus more susceptible to "bubbles/blisters".



Reprint from Scientific America

Overview/Hydrostatic Vapor Matters

- Hydrostatic pressure problems can be encountered anywhere.
- One source of the problem is the inherent characteristics of concrete.
- Hydrostatic pressure problems are the "Achilles' Heel" of flooring contractors and coating suppliers.
- There is no remedy that provides a 100% solution to this occuring problem since all concrete has latent moisture and vapors in the concrete that are always trying to migrate out of the concrete.
- New volatile organic content (VOC) applied coatings add to the " bubbles/ blisters" problem.
- Urethane coatings can not be applied over concrete, without the risk of bubbles/blisters occurring
- No coating adheres to concrete so well that it is able to resist powerful hydrostatic forces.

Check List(to help minimize vapor "bubbles/blisters" - new construction)

- Did sub-grade include 4-6 inches of crushed rock; 2-3 inches of sand, and a properly engineered vapor barrier (40-60 Mils) with no breaks/ tears?
- Was the concrete poured under acceptable conditions? (i.e. not poured over standing water/snow/ice?
- Hardners/ curing compounds used?
- Water-cement ratio correct?
- 4000 - 5000 PSI concrete?
- Cured at high temperatures (77˚f and higher) minimum 28 days (longer is better).

MORE TO EXPLORE/ REFERENCES USED

A portion of the material for this article was taken from

"Concrete, Coatings and Failures—An Overview" (1993) by Richard A. Burgess, KTA-Tator, Inc., Houston, TX and Eric S. Kline, KTA-Tator, Inc., Pittsburgh, PA.

"Testing Moisture Content in Concrete Subfloors Prior to Installing Floor Coatings" by Peter E. Nelson and Dennis J. Pinelle, Simpson Gumpertz Heger Inc.

"Prevention of Moisture Related Disbondment of Non-permeable Flooring Systems"

"Testing & Inspections" by George Donnelly, Hemet, Ca.

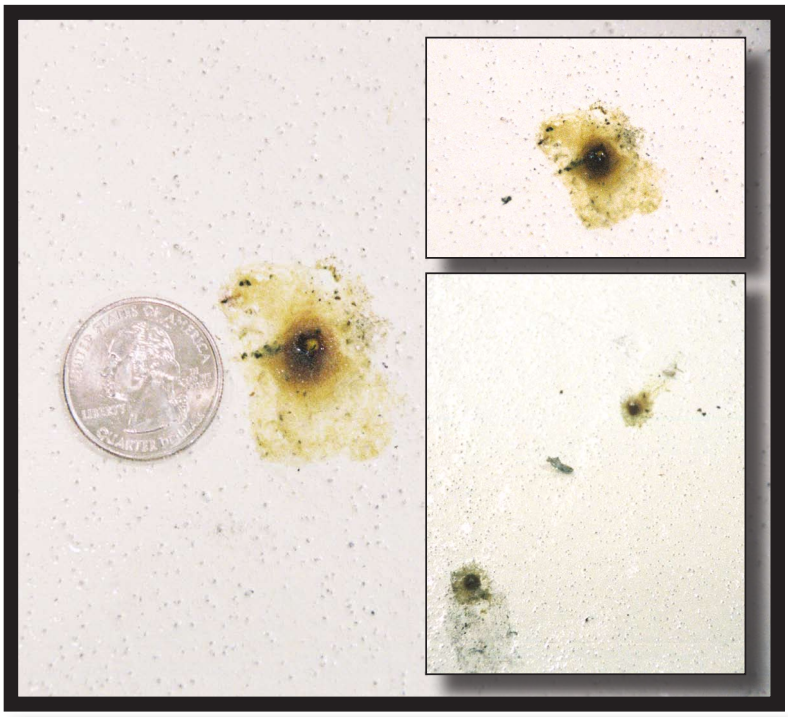
" Our Ever Changing Earth" Scientific America

" Understanding Paint" by Wayne R. Fuller

Postscript 6/06 (An actual hangar hydrostatic pressure problem example)

A hangar displaying hydrostatic pressure problems. Note the "oily puss" emitting from the hydrostatic bubbles. This hangar has been coated four times in the past 25 years (that we know of). No one, no product, no company has been able to solve the trapped moisture and contamination/ hydrostatic pressure problem.

Even complete removal (shot blasting/diamond grinding) and recoating would not eliminate the "problem." The moisture/contamination would be "forced" up again, resulting in the same phenomena. The best option is to continually repair broken/open bubbles and recoat at a 2-4 year interval.



Bubbles with "puss" coming to the top and staining the floor. The puss is a combination of water, chemicals, fuels, oils, various hydrocarbons, sodium/calcium/magnesium salts, etc.

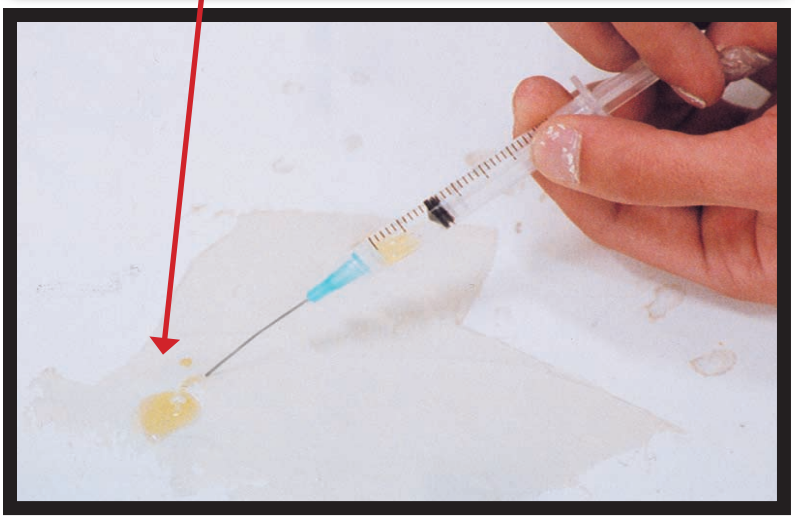
The "puss" is easily removable by scrubbing, but the bubble release point is still there and comes back in time.

Postscript 12/05

The attached photographs shows a beautiful, hangar. Unfortunately, the floor has hydrostatic pressure problems, but mainly isolated to one, small area.

When a highly cross linked, dense urethane (that cannot breathe) is used, this is sometimes the result. Fortunately, the overall result outweighs the problem areas. There is no solution except removal and repouring of the concrete, or applying a breathable coating system (of course, with a loss of performance properties, e.g. gloss, color retention, chemical/abrasion resistance, etc.).

The moisture bubble problem was so severe, we were able to pull almost 2ml out of one bubble. Again, fortunately, this was isolated to one small area of the hangar.



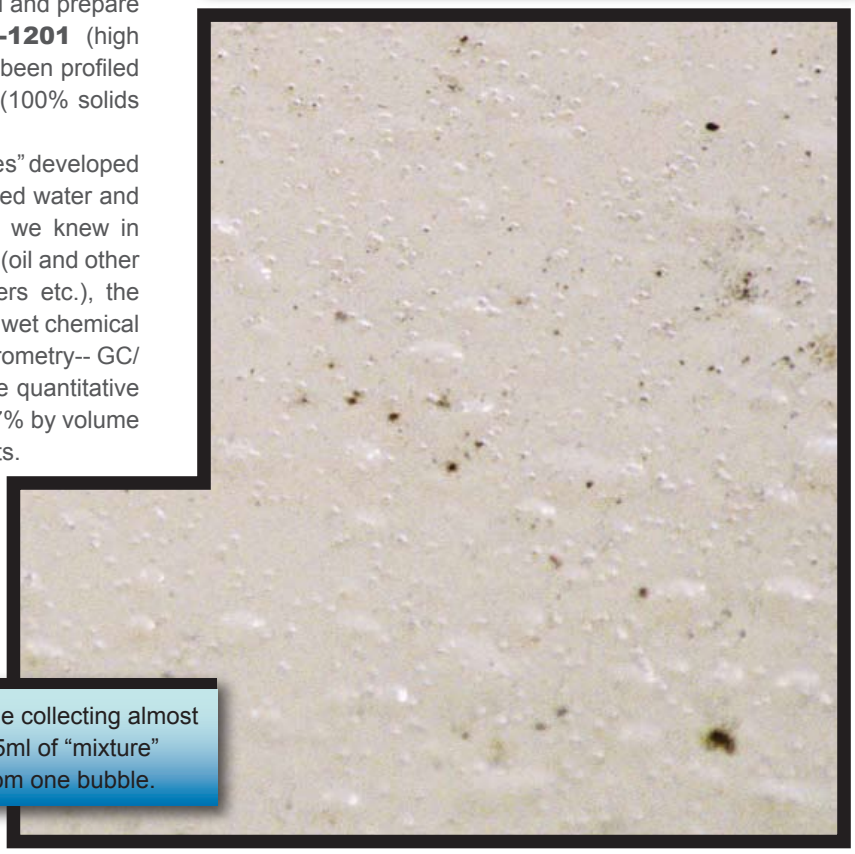
CORPORATE HANGAR ATLANTIC AVIATION

Postscript 8/05 and 6/06

For this hangar, the final coating steps were started on 8/27/2005 with a plan to clean, sand and prepare the surface for the final application of **U31-1201** (high performance urethane topcoat). The floor had been profiled previously and **E31-1202** had been applied (100% solids epoxy squeegeed and back rolled).

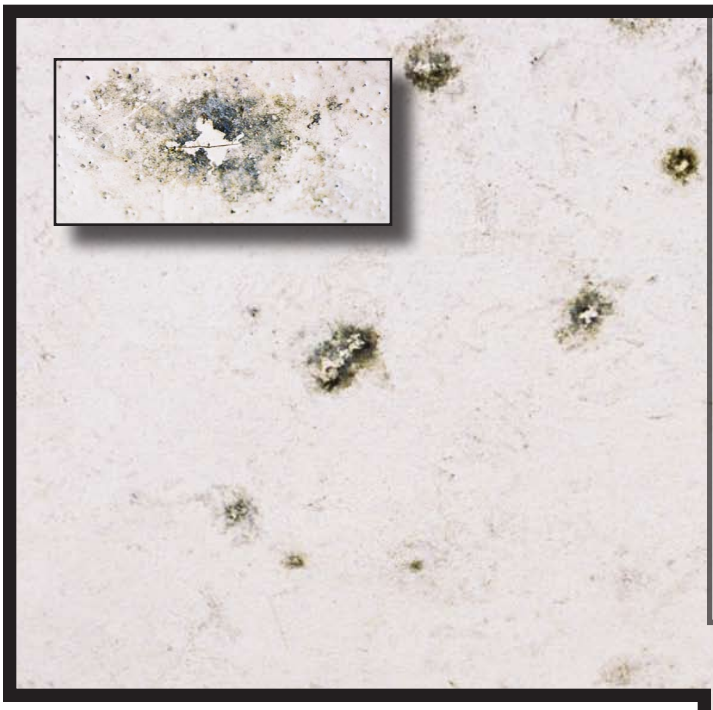
Before all of this could be done, "bubbles" developed in one 25' x 25' square. Visual analysis indicated water and an "oily" mixture under the bubbles. Though we knew in advance it was a combination of aviation fluids (oil and other various hydrocarbons, skydrol, avgas, cleaners etc.), the liquid was pulled out by syringes and tested by wet chemical techniques (gas chromatography / mass spectrometry-- GC/MS) for component weight / weight percentage quantitative analysis. The analysis showed greater than 97% by volume H_2O with all of the other above in trace amounts.

Bubbles/ Water, Oil, Chemical Mixture



Syringe collecting almost 1.5ml of "mixture" from one bubble.

Bubbles broken with"chemical" mixture staining the floor.



Postscript 8/05 and 6/06 (cont.)

For this same hangar, the attached photographs were taken 6/06 [almost ten (10) months later] and show the hydrocarbon mixture forced up by hydrostatic pressure, cracking the surface with the "oily mixture" being emitted. This "eruption" is easily cleaned off with a soapy solution, a clean solvent (i.e. acetone), or other means, leaving the cracked surface. No concrete is exposed.

The hangar, built in the 50's, was exposed to piston/turbine "leakage" for many, many years before the floor was coated. There is no means to extract the contamination since it occurred over such a long period of time and is so deep (short of jack hammering out the concrete and repouring). This area has been removed to bare concrete and shot blasted/diamond ground twice, but again, the contamination is so deep and plentiful, and with no means for extraction ,the "bubbles" reappear each time this area is coated (as soon as the floor is cooled and then heated up, expanding the liquids below).