AMERICAN CONCRETE PUMPING ASSOCIATION

ACPA SAFETY BULLETIN

HOSE WHIPPING: PART I

Background Information

Air ingression to concrete pumping delivery pipelines has revealed itself as a considerable hazard under certain circumstances. Injuries to placing crew personnel have been sustained when trapped air is momentarily compressed, then released, causing the end hose to whip violently. The list of circumstances leading to hose whipping continues to evolve as knowledge is gathered from the field. Presently, we know there are three factors that must come together for a hose whipping hazard to exist:

1. There must be air in the delivery system,
2. There must be something pushing on the air, and
3. There must be a restriction near the hose so the air compresses.

Air in the delivery system by itself poses no particular hazard; e.g. whenever delivery system is cleaned out, it's full of air. It's only when the air is compressed, thereby storing energy, that a hazard is created.

Avoiding Hose-Whipping Accidents

To avoid injury by a hose moving from release of trapped air, personnel must be out of the end-hose movement area.

Because the conditions creating the hazard (air is being pushed by the material being pumped) don't usually result in hose whipping, knowing when the hose will whip is not feasible. It is possible, however, to be aware that the conditions creating the hazard are present and warn personnel in the discharge area to remain away until the conditions no longer exist.

Debris coming from the hose during release of trapped compressed air can also be a hazard. To protect against the debris, personnel should move a prudent and reasonable distance beyond the end-hose movement area or the point of discharge, and Personal Protective Equipment (PPE) should be worn.

The end-hose movement area is defined as the area within the radius of the last flexible (non-steel) piece of delivery system. For example, if ten feet of rubber hose is attached to a pipeline, personnel standing more than ten feet away from the point of attachment are outside the end-hose movement area. See figure 1.

This may appear to be in conflict with other safety publications, which have stated that personnel should remain back fifty feet whenever air is in the system. In fact, fifty feet was used in documents intended to be distributed to job-site personnel and their supervisors simply as a nominal figure easily remembered. If there is only ten feet of flexible delivery system attached, personnel positioned eleven feet away should not be hit by the hose, although the hazard of flying debris remains for some distance around the point of discharge.

How Air Gets in the Delivery System

Listed below are the ways air can be introduced into the delivery system. These are situations making the hazard possible, and it is when these situations are encountered that personnel should be warned to clear the discharge area.

1. **The delivery system is void of concrete, and is therefore full of air.** Examples:

   1.1 when **first starting,** or

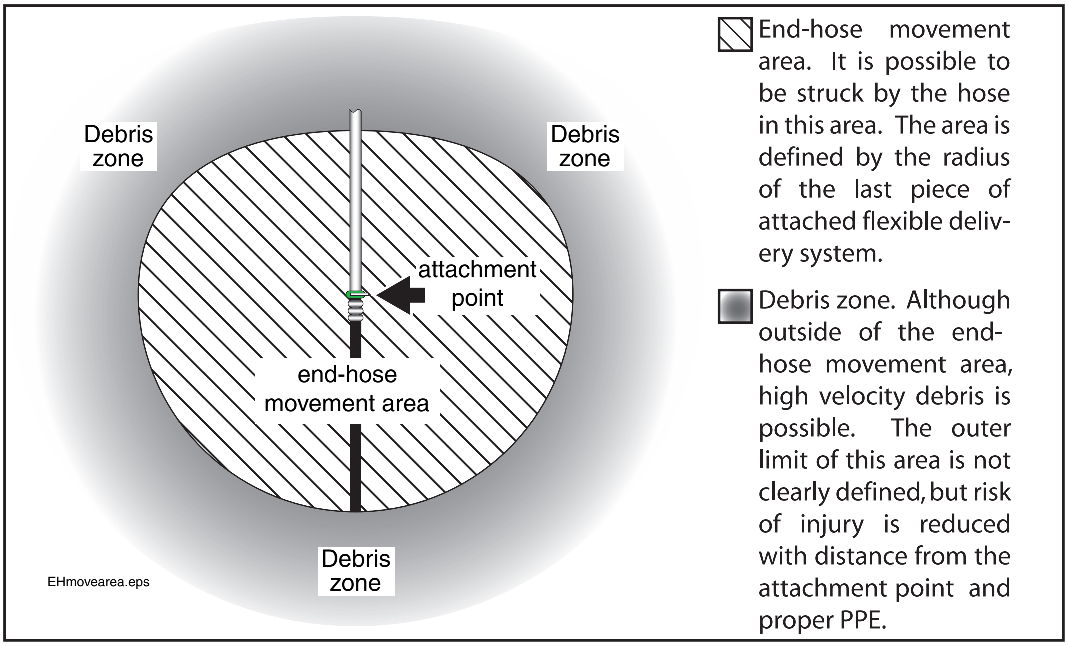


Figure 1
End-hose movement area

1.2 when **restarting after moving.**

2. **The pump sucks air into the material cylinders through the hopper.** Air ingression through the hopper happens when:

   2.1 the **pump is first started at the beginning of the job,** or

   2.2 the hopper goes empty because **the pump is pumping faster than concrete is being delivered,** or

   2.3 the hopper goes empty because **the pump continues to pump after the ready-mix truck stops delivery or after it's completely discharged,** or

   2.4 **the concrete is so stiff that air is being taken into the material cylinders with the concrete.** In this case the concrete must be so stiff that bridging is occurring.

3. **Air is introduced through the tip hose.** This type of ingression happens when:

   3.1 **the pump is operated in reverse** for any reason, or

   3.2 **the pump is shut off during pumping**, and the boom's tip section is in a generally down position, such as that shown in figure 2, or

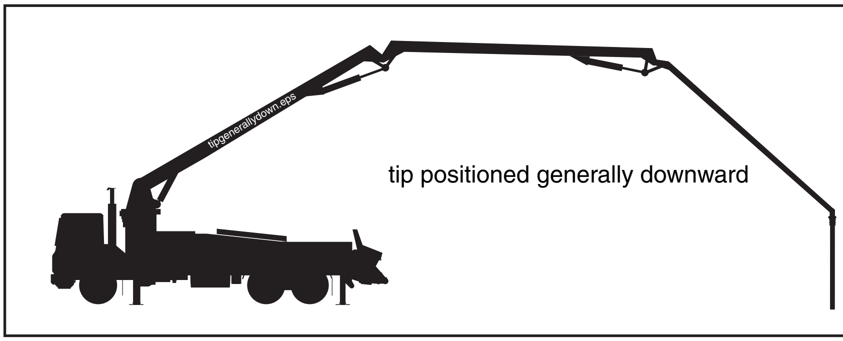


Figure 2
Tip section downward

   3.3 a **blockage has been successfully removed** by performing the operation known as "rocking the concrete."

   3.4 the **concrete being pumped borders on "unpumpable,"** As the operator frequently changes between forward and reverse in an attempt to “rearrange the rocks”, the concrete is coming out in jerks. In the time between squirts of concrete, air is filling the gaps.

4. **Air is introduced into the interior of the pipeline, other than at either end.** This happens when:

   4.1 the **pump is operated in reverse, or stopped** while concrete is in the pipeline, and **one or more pieces of pipe have a hole in them,** or

   4.2 the **pump is operated in reverse, or stopped** while concrete is in the pipeline, and **gaskets at the clamp joints are missing or badly damaged,** or

   4.3 the **pipeline is disassembled, then reassembled.** This is a common occurrence when removing pieces of pipe from a horizontally laid pipeline during the course of a day. The hoses are disconnected, one or more pieces of pipe are removed, then the hoses are reattached, or

   4.4 a **blockage has been manually removed** from a reducer, hose, pipe, or elbow, after which the pipeline is reassembled.

Pressurizing the Air Pocket

How much pressure it takes to move concrete in a pipeline depends on several factors:

- The distance the concrete must travel.
- The diameter of the delivery line.
- The composition of the delivery line (hose or pipe, how many elbows, radius of the elbows).
- The pumping rate (100 yards per hour takes much more pressure than 50 yards per hour).
- The composition of the concrete (pumpability and dryness).
- The vertical level difference between the point of placement and the pump (each foot of level difference adds 1.1 PSI, regardless of the angle creating the level difference).

Assuming a pipeline is laid horizontally, the pressure required to push concrete is a linear function of the distance the concrete must be pushed. In other words, at halfway to the end, it only requires half the pressure to move the concrete, as shown in figure 3.

Once inside the pipeline, the air is pushed by the concrete coming behind it, and, in turn, pushes the concrete in front of it. Within moments, the air pressurizes to the same pressure required to push the concrete in front of it. When the air pressurizes, it takes less space, in much the same way a spring takes less space when a force is applied.

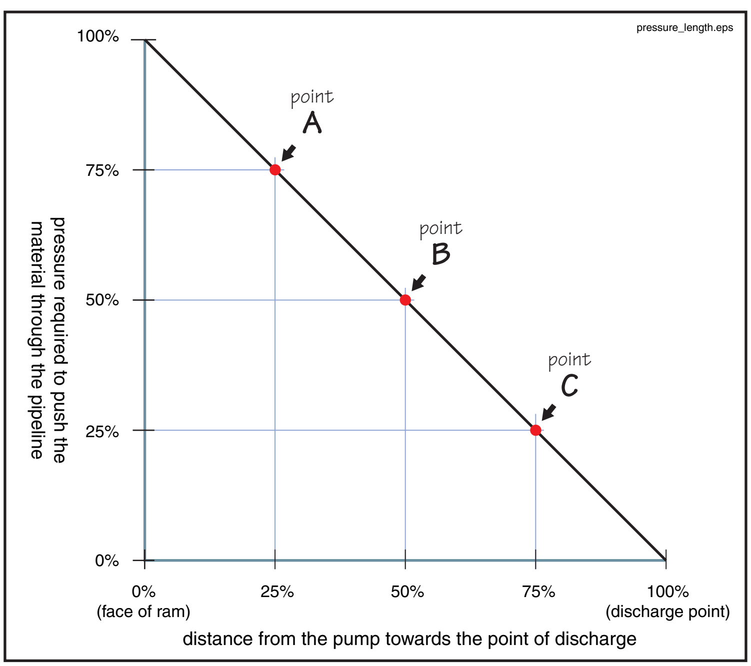


Figure 3
Pressure as a function of distance

As the air travels through the pipeline, it takes less and less pressure to push the concrete in front of it, (because there's less and less concrete in front of it). As the pressure drops, the air expands, taking more space than it had a moment before. As it expands, the concrete in front of it must move faster to accommodate the ever-expanding air pushing it. See figure 5.

The vast majority of the time, concrete accelerating in front of the air pocket results in a harmless escape; the concrete squirts out rapidly, there's a small "puff" as the air escapes, and the concrete behind the air resumes flowing normally. Perhaps the hose gives a small jerk and there's some splattering by the air/concrete mixture. No one is at risk in this case.

A small percentage of the time, the material accelerating in the delivery system gathers in the hose or reducer and forms a blockage. The fact that air is forcing the material to accelerate rapidly may cause some segregation of the material components, thereby increasing the chances of blockage formation. Whatever the cause, once a blockage has formed in front of air, the hazard is in place.

In the best-case scenario, the blockage releases with minimal pressure increase, or the blockage is so complete that even when the pump reaches maximum pressure, it does NOT release. In the latter case, there is no expulsion, the pump stops moving material as the hydraulic relief systems are activated, and the operator can relieve the pressure before looking for the plug.

In the worst-case scenario, high pressure is exerted on the air pocket before the blockage releases, and the reaction of the air escaping at high velocity causes the hose to whip violently. See figure 4.

Remedial Measures

Hose whipping accidents can be avoided if people take the proper precautions when air has been taken into the delivery system. Each person involved has to know what to do, and knowing is a matter of education. Everyone needs specific knowledge, and each person has to heed the warnings to protect themselves. Communication between the personnel is crucial.

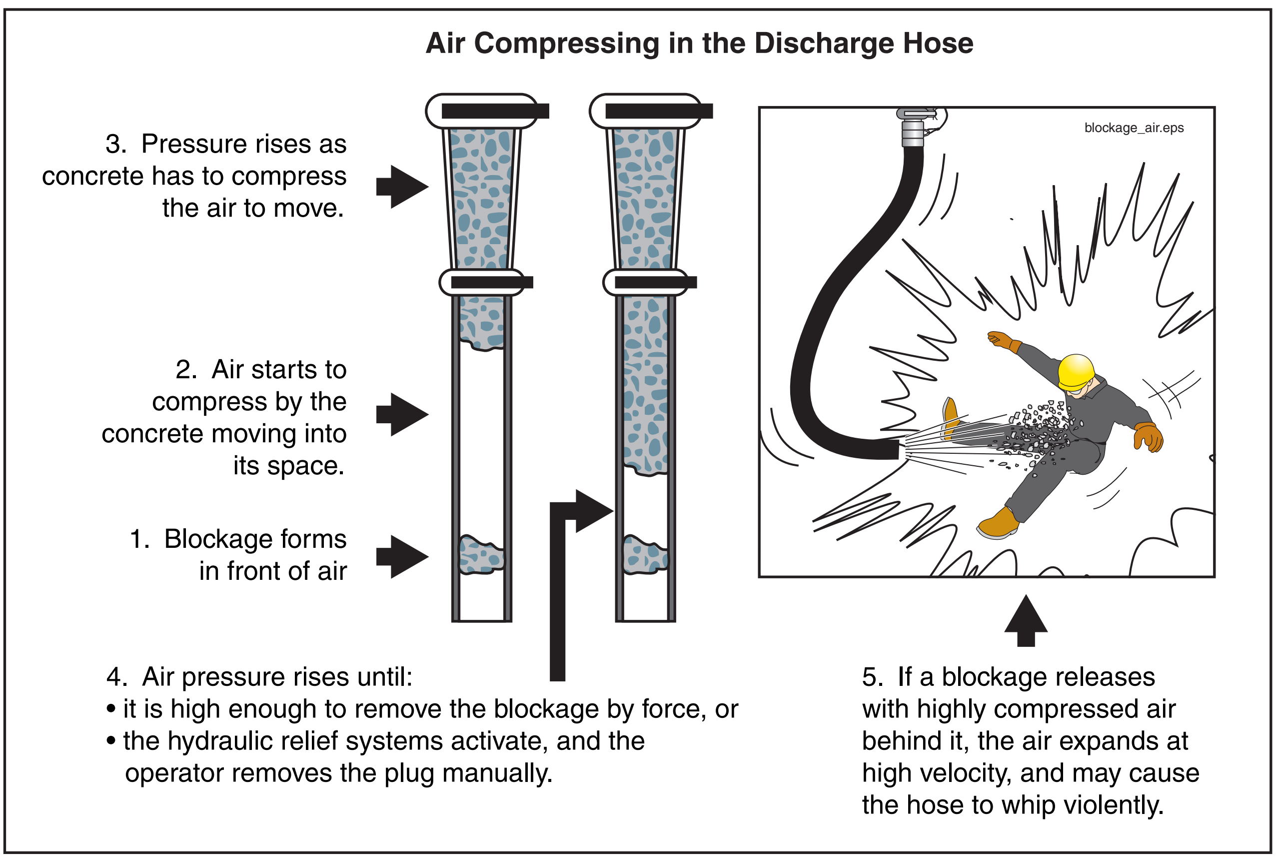


Figure 4
When air compresses in or near the tip hose

Boyle's Law

$$\frac{\text{Initial Pressure}}{\text{Final Pressure}} = \frac{\text{Final Volume}}{\text{Initial Volume}}$$

Example: A material cylinder 9 inches in diameter and 80 inches long takes in a half gulp of air. This results in 2535 cubic inches of air being forced into the delivery system pipeline. In our example, the concrete requires 800 PSI of pressure to push it through the entire length of pipeline. The air pocket compresses until it's at 800 PSI, too. At that pressure, the 2535 cubic inches of air has become only 2.5 inches long in a 125 mm pipe.

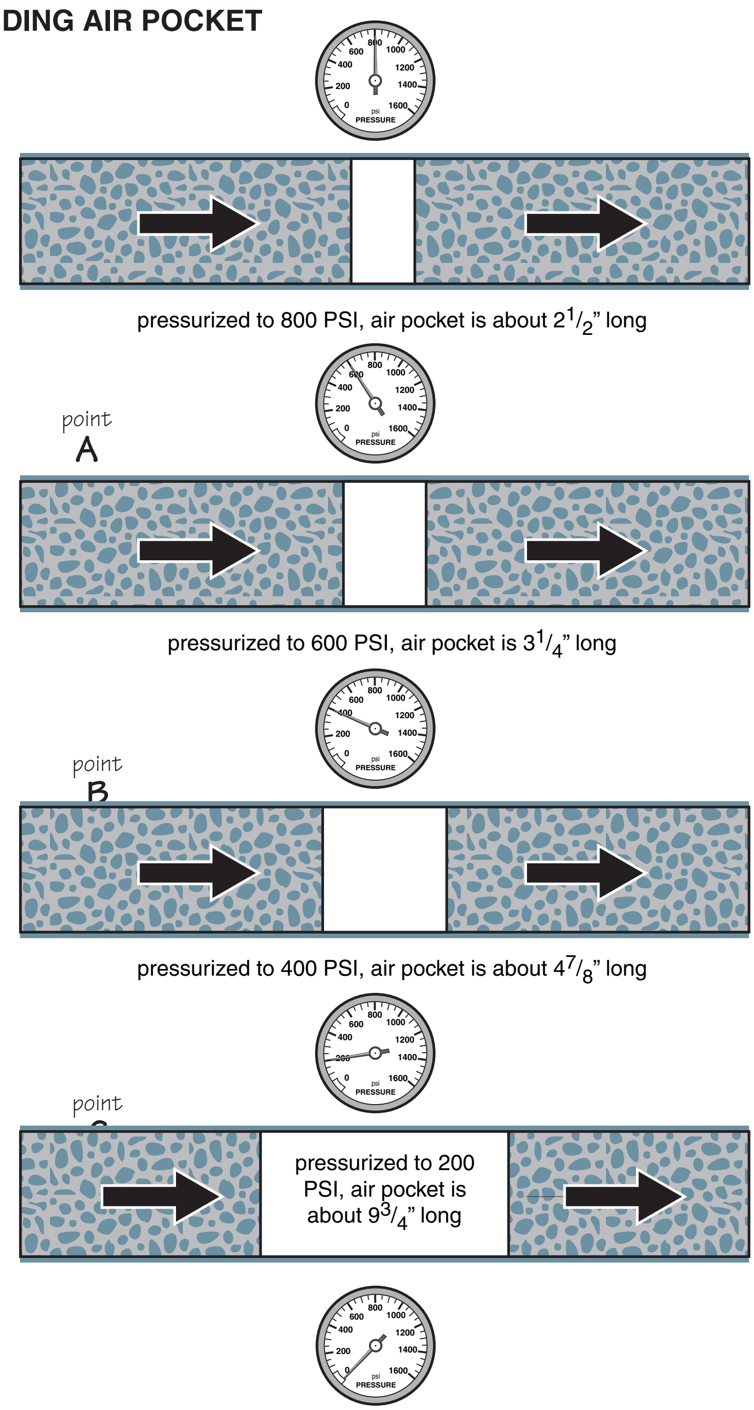
When the air has traveled 25% of the distance towards the end (point A in figure 2), the pressure has fallen 25%. Because of that, the air pocket increases in size. At 600 PSI it is about 3 1/4 inches long.

At halfway to the end, the pressure has fallen to half the original pressure, so it's now at 400 PSI (point B in figure 2). That allows the air to decompress more, and it is now almost 5 inches long.

When the air has made it 75% of the way to the end, air pressure will have fallen 75% from the original value (point C in figure 2). At 200 PSI, the air pocket is about 9 3/4 inches long.

Between the time the air pocket leaves point C, and when it arrives at the end of the delivery system, it will increase to it's original size of 133 1/4 inches (11 feet, 1 1/4 inches). Because it is getting larger, it must push the concrete in front of it faster to make room for itself. The concrete accelerates, (there's only atmospheric pressure in front of it) which can cause forceful ejection of the rocks and sand, followed immediately by the air pocket.

Concrete arriving after the air is unaffected by the air pocket it was pushing.



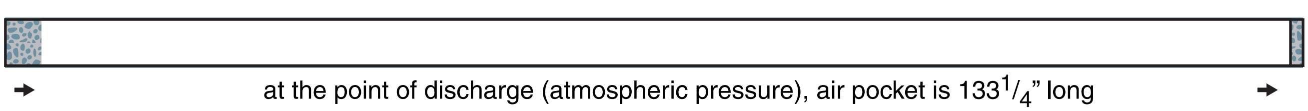


Figure 5
Air expands as pressure drops

1. Operators:

1.1 Must know how air enters the delivery system, and the severity of the hazard to the placing crew.

1.2 Must know to warn personnel to stay away from the discharge whenever air is known to be in the delivery system.

1.3 Must communicate the hazard and its severity to the placing crew and laborers, or verify that they already know it.

1.4 Must communicate the hazard and its severity to the ready-mixed concrete truck drivers so they'll know to take preventive action if air enters the system through the hopper, or verify that they already know it.

1.5 Must know to minimize the chances of developing blockages when air is known to be in the system; for example, slowing the strokes per minute.

1.6 Must know how to minimize the effects of air in the delivery system, such as reversing the pump if air was introduced into the system through the hopper, and pumping slowly until the air is expelled.

2. Laborers assigned to work at the pump:

2.1 Must know the hazard, its severity, and the methods of air ingression.

2.2 Must know how to alert the operator or stop the pump if they see that air has entered the system through_the hopper.

3. The placing crew:

3.1 Must know the severity of the hazard.

3.2 Must know how to recognize clues that air may be in the system. For example, they must know that every time they remove a piece of pipe from a system, air is introduced, and that there's always air when first starting or restarting after moving.

3.3 Should know the telltale signs of a blockage in a hose and what to do if they suspect a blockage in a hose has occurred.

3.4 Must heed the warnings from others and remain away from the point of discharge until the operator verifies that the hazard has been eliminated.

4. Ready-mixed concrete truck drivers:

4.1 Must know to keep the hopper level full, and to alert the operator or stop the machine if air is taken into the pump.

4.2 Must know of the severity of the hazard if they are to be expected to take this responsibility seriously.

4.3 Must know how the operator would prefer to be notified in an emergency, and how to activate the emergency stop switches if they cannot get the operator's attention.

5. Contractors:

5.1 Must know how air enters the delivery system, and the severity of the hazard to the placing crew.

5.2 Must know to warn personnel to stay away from the discharge whenever air is known to be in the delivery system.

5.3 Must communicate the hazard and its severity to their foreman, the placing crew and laborers, or verify that they already know it.

Summary

Every person in the chain of a pumping job has a responsibility to help protect the hose person and other nearby personnel from hose whipping accidents. Education is the key, followed closely by diligent watchfulness and PPE. Educational materials are available from the ACPA, but the people in the industry who know of the hazard must take steps to make the supervisors of the other industries aware that the problem exists and that there are materials available to teach avoidance.

- By Robert Edwards,

Edited by the ACPA.