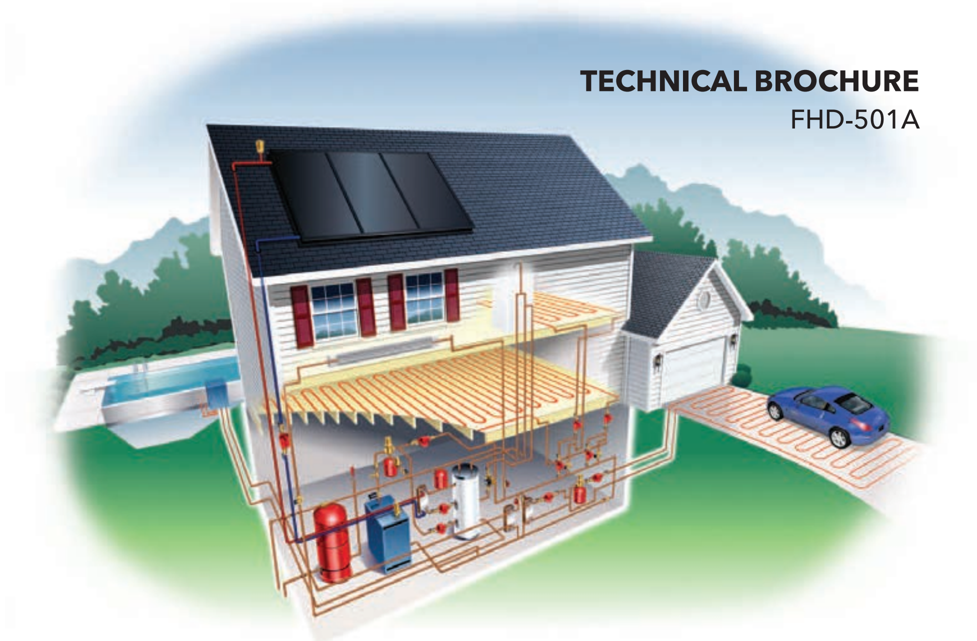
TECHNICAL BROCHURE

FHD-501A



CounterPoint

How Hydronic System Components Really Work

Bell & Gossett

a xylem brand

Preface

There was once an old-timer who was charged with teaching an apprentice a thing or two. The apprentice was young and eager to learn, and it seemed as though there was so much to learn back then.

One day when they were working together the apprentice looked over the old-timer's shoulder and out of honest curiosity asked, "Why are we doing it that way?"

The answer came back like a slap in the face.

"What's your point?" the old-timer asked, narrowing his eyes.

The young apprentice didn't know what to say. The old-timer had turned on him so quickly.

"What do you mean?" the apprentice finally asked, backing up a step.

"I mean, what's your point? You trying to say you think there's a better way to do it? Are you questioning what I'm trying to teach you here, Kid? Huh?"

The apprentice looked at his shoes and said nothing. The old-timer nodded slowly to himself and said in a very deliberate way, "We do it that way, Kid, because I say so. Do you understand?"

The apprentice quickly nodded, not sure what he had said wrong, but marking this moment in memory. This would never happen to him again. Ever.

"Now, do you have any more dumb questions?" the old-timer asked.

The apprentice shook his head.

"Can we get back to work now?"

He nodded, saying nothing.

"Thank you," the old-timer spat out, turning back to his work.

As the years went by, the apprentice grew in experience, but he never did get that solid base of knowledge that he needed to be better than average. He always hesitated to ask questions. Before long, the people around him just assumed he knew things.

The trouble was, he didn't. And he always worried that someone would find out. So when he was asked a question that made him uncomfortable, he would often answer with a steely eyed question of his own.

"What's your point?" he'd say.

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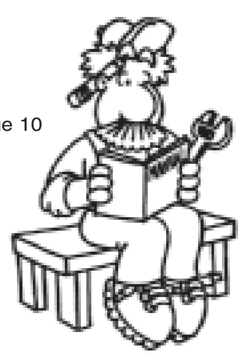

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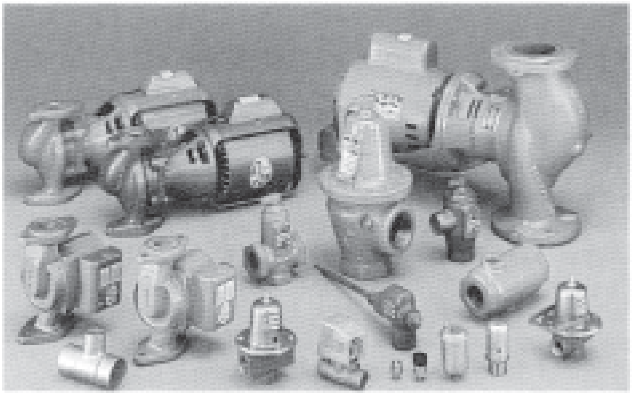


Do you ever stop to think about how hydronic system components work? What's inside of these things? How does a circulator move water? Does it always create a positive pressure? What's the real job of a feed valve? Does a Flo-Control valve actually control flow in the system? Does every system need an air separator? How do air separators remove air from water? Are all relief valves the same?

You can work in the field for years without really understanding how key system components work. If you put the parts together and everything works as it should, you're home free! But if your system doesn't perform as promised, you're going to have to do some troubleshooting. And successful troubleshooting begins with a knowledge of how the system components really work.

Knowledge broadens your options. It's the best tool a heating professional can carry. Knowledge is what separates the trouble-shooters from the parts-replacers. And knowledge is what you gain when you separate the "Old-Plumber's Tales" from the facts.

With that in mind, let's take a look at some basic hydronic system components and see what makes them tick and how they tie together to make up a good system.

The All-Important Relief Valve

Every boiler needs a relief valve. Unfortunately, our industry discovered this fact of life the hard way. There was once a time in the early days of heating when boilers exploded like clockwork. The reason was simple: those early boilers had no way of relieving excessive pressure. The introduction of the modern, spring-loaded relief valve changed all that and saved many lives.

A brief job description...

The relief valve's job is to protect the boiler against the dangers of thermal expansion. Should the pressure rise to the boiler's maximum working pressure, which is established by the manufacturer and tested and confirmed by A.S.M.E. (the American Society of Mechanical Engineers), the relief valve will open and release the excess water.

A modern relief valve uses a spring-loaded diaphragm to hold the valve closed. Manufacturers set the spring to push down against its side of the diaphragm with a certain predetermined pressure. On residential systems, this pressure is usually 30 psi, the maximum working pressure of most household boilers. Tall buildings generally need boilers that can operate at higher pressures. We set those relief valves to open at settings higher than 30 psi.

Think Safety!

Never use a relief valve that has a pressure-relief rating higher than the maximum working pressure of the boiler. And under no circumstances should you ever plug a relief valve to stop a leak, even if it's only for a few minutes. Nor should you pipe the valve's discharge to the outdoors. If you do, the relief valve might discharge, and the water that doesn't drain from the line could freeze. A block of ice in the relief line can be as dangerous as a pipe plug.

Some contractors think that as long as they pitch the relief valve's discharge line down, it will drain fully, but this isn't what actually happens. Picture this: the valve pops open and the discharge line fills with water. Some of that water drains, but some also stays in the pipe where it can freeze. The water stays in the pipe because air can't get into the top of the pipe (the relief valve end) to break the partial vacuum formed by the falling water. It's the same principle that keeps liquid in a straw when you hold your finger over the end and lift it from the glass. This is why you should never discharge a relief valve to the outdoors.

Always connect the relief valve directly into the boiler, and never put it up on a nipple. You want that valve to be as close to the boiler as possible, so it can sense what's going on and react as quickly as possible.

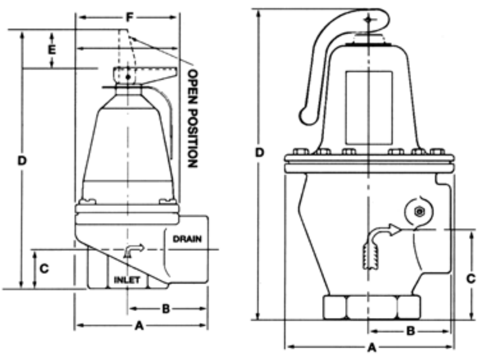
You should also keep the relief valve's boiler tapping full size, and of course, make sure there are no valves between the boiler and the relief valve that could be accidentally closed. This seems like a silly point to have to bring up, but it has happened.

The proper setting and capacity

In addition to the pressure-relief setting, manufacturers rate relief valves to release the full Btu load of the boiler. This is very important because when there's an emergency, the boiler's "exit door" has to be large enough to safely relieve everything that wants to rush out. If all that energy can't get out of the boiler in an orderly way, pressure will build inside the boiler and lead to a dangerous situation, even though the relief valve is wide open! Make sure that this all-important rating meets or exceeds the boiler's D.O.E. Heating Capacity rating.

You should always treat relief valves as though they were as fragile as raw eggs. Never drop them on the floor or bang them with a tool. And never try to "recycle" an old relief valve by installing it on a new boiler. The risk you take is just not worth the few dollars you might save.

All relief valves are not equal



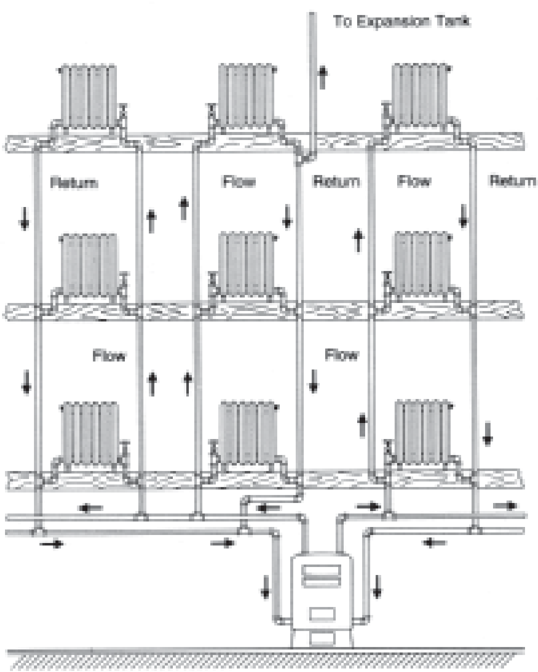
When we designed our B&G A.S.M.E. relief valve, we gave it a diaphragm that has about five times the area of those you'll find in a "pop-type" relief valve. This larger diaphragm area gives you a greater operating force, and that helps to overcome the effects of fouling on the valve's seat. B&G ASME-rated valves also feature a unique fail-safe disc that allows the valve to work even if the diaphragm should rupture. They're an excellent choice if you're looking for a valve that can be opened for periodic testing and still last for many years to come.

Size, Capacity & Relief Setting for B&G ASME Safety Relief Valves[1]				
Relief Setting PSIG	Model Number Capacity in BTU Per Hour			
	Iron Body		Bronze Body	
30	3301-30 3,300,000	4100-30 4,100,000	790-30 790,000	1170-30 1,170,000
36	3301-36 3,800,000	4100-36 4,600,000	790-36 900,000	1170-36 1,330,000
45	3301-45 4,500,000	4100-45 5,515,000	790-45 1,065,000	1170-45 1,575,000
50	3301-50 4,900,000	4100-50 5,990,000	790-50 1,160,000	1170-50 1,710,000
75	NOT AVAILABLE		790-75 1,615,000	1170-75 2,385,000
100			790-100 2,075,000	1170-100 3,060,000
125			790-125 2,535,000	1170-125 3,735,000

[1] Contact your local wholsaler or Bell & Gossett representative for availability of ASME Safety Relief Valves with special pressure settings.

The Pressure-Reducing or "Feed" Valve

The pressure-reducing or "feed" valve's job is to fill the system with water and to keep that water under a few pounds of pressure at the top floor. Your job is to figure out how much pressure you need in the basement to push the water up to the top of the system and hold it there under pressure.



In the beginning...

We haven't always had feed valves on hot water systems. No, in the beginning, the old-timers did things differently; they filled the systems from the top instead of from the bottom.

Back in the days of gravity hot water heat, an old timer would use an open expansion tank up in the attic. Since the tank was the high point of the system, he knew he could fill all the pipes from there.

Filling the system wasn't always an easy job. In fact, before there were city water mains, the old-timer would have to carry buckets of well water up to the attic tank. Later, when pressurized water mains became available, he most likely used a ball cock in the open attic tank to maintain a water level and keep the system filled.

Water has weight!

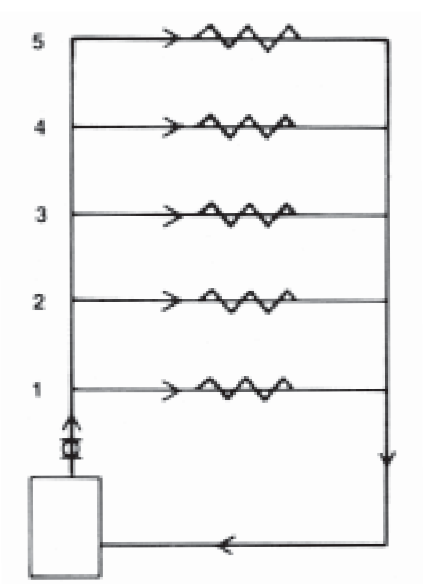
Now, water has weight, and the higher you stack it, the more it will weigh at the bottom. It's like bricks. The higher the pile, the more it weighs, right? Same thing with water.

And since weight exerts pressure downward, you could put a pressure gauge in the boiler and read the weight of the column of water in "pounds per square inch." This, by the way, is the same pressure that affects deep-sea divers. If those folks dive too deep, the weight of the water will crush them.

We call the weight created by the height of the water in a heating system "static head pressure," or static pressure for short. Static pressure is pressure that's there all the time. The further down in the system you go, the higher the pressure will be. That makes sense, doesn't it? As you go lower, you're putting more water on top of yourself. More water means more pressure. If you've ever tried to take a wrinkle out of the bottom of a swimming pool liner after you filled the pool with water, you know about static pressure!

So when the old-timer filled the gravity hot water system from the tank in the attic, he created a static pressure down in the boiler. The taller the building, the higher the pressure on the boiler. This means that the height of the system determined the working pressure of the boiler. If the boiler were rated for 30 psi, for instance, the relief valve would pop if the old-timer stacked too much water on top of it. If he was working with a very tall building, he'd have to use a boiler with a higher working pressure.

Square inches and round dimes



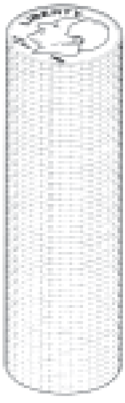
Today, most of your systems don't have open tanks in the attic; they have "closed" steel compression tanks or diaphragm-type tanks, and most of the time, these tanks are down in the basement. You don't pour water into the system from the top any more, do you? No, you force it up from the bottom. And that's where the pressure reducing valve comes in.

The PRV takes the high pressure from the city water main and lowers it to the amount needed to lift water to the top of the building.

Once you fill this "closed" system with water, you'll have the same static-pressure effect at the bottom as you did in the "open" gravity system. The only real difference is the point at which you fill. But if you're filling from the bottom, how do you know how much pressure you'll need to fill the system to the top? Most standard feed valves come factory-set at 12 psi (they're adjustable between 10 and 25 psi). Is that enough pressure for most buildings? Why do the people at the factory set them at 12 psi and not some other pressure?

The answer is simple: A column of water 2.31 feet high (that's about 28 inches) will exert one pound per square inch (psi) of pressure down on the bottom. And it doesn't matter how wide or narrow that column of water is. It could be a 3/4" pipe, or it could be a swimming pool. If the water is 2.31 feet deep, there's going to be one pound per square inch of pressure at the bottom.

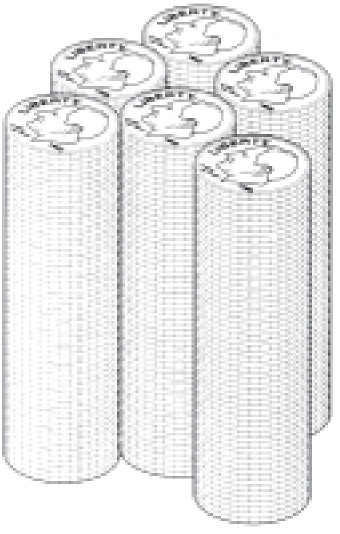
The reason you can be so sure of this is because you're measuring a pound per square inch (psi). A square inch will always be a square inch, no matter what.



Here, let's look at it a different way for a moment. Imagine that instead of working with water, you're working with a stack of dimes.

We'll create a new term for this example - "pounds per round dime." Using that term, can you see how the weight at the bottom of the column of dimes will be equal to the amount of dimes you stack on top of each other?

But suppose there were more than one stack of dimes?



Has the term "pounds per round dime" changed? No, it hasn't. Sure, there are more dimes now, but the height of the columns hasn't changed.

This is essentially what happens in a larger-diameter pipe. There's more water, but the weight at the bottom in pounds per square inch remains the same. The height of the column not the quantity of water, determines the static pressure in the system.

So if you set a feed valve for one pound per square inch, it will lift water into the system exactly 2.31 feet above the feed valve. Any piping lower than the feed valve will, of course, also be filled with water. Gravity takes care of that.

It's important to mention here that this fill pressure has nothing to do with the number of fittings or valves or the width of the building's piping network. Those things affect the circulator, and we'll talk about them later. But for now, just keep in mind that the only thing that determines static head pressure is the height of the water in the system.

Why 12 psi?

So why do most manufacturers set their residential feed valves (such as the B&G FB-38TU) at 12 psi? Well, let's look at a "typical" house where you might install that valve.

You've installed the feed valve in the basement, naturally. You've piped it at a convenient height, say, about four feet below the basement ceiling. Now, let's figure out how high the feed valve has to lift water to get it to the top of the system in this house.

Well, we already said it's four feet to the basement ceiling. Let's add another foot of lift to get through the basement ceiling. That puts you on the floor of the first story. Now this happens to be one of those old Victorian houses with a ten-foot ceiling, so add ten feet to get yourself up to the ceiling of the first story. Now you're 15 feet above the feed valve. Throw in another foot for the first-floor ceiling and an additional three feet to get yourself to the top of that old cast-iron, water-tube radiator. That gives you a grand total of 19 feet from the feed valve to the top of the system.

Time for a little math. If you need 1 psi to lift water 2.31 feet, how much pressure do you need to lift water 19 feet? That's simple!

19/2.31 = 8.23 psi

So you need just a little more than 8 psi at the outlet of the feed valve to fill the system in this "typical" house. That gets the water up to the top floor radiator, but once it's up there it won't be under any pressure. Remember, static pressure reflects the weight of the column of water. But if you're at the top of the column, there's no weight at all, is there? And since no weight means no pressure, you won't be able to vent much air from that top-floor radiator, will you?

Also, suppose someone should set the high-limit aquastat higher than 212 degrees F in this system. When that hot water gets to the top where there's no pressure, it can flash to steam. That's not only noisy, it's also destructive and dangerous. So, to avoid these problems, you should always add three or four more pounds of pressure to the feed valve's setting to give you a positive pressure up at the top of the system.

That's why we set standard feed valves such as the FB-38TU at 12 psi. We designed it for the "typical" two-story house.

But suppose the building you're working on is taller than two stories. You'll have to increase the fill pressure to reach the top floor, won't you?

What settings?

Here are some sample buildings. See if you can figure out how much fill pressure you need in each of them.

As you can see, once you get to a certain height, you have to start thinking about the working pressure of your boiler. For instance, putting a boiler with a 30-psi working pressure in the basement of a five-story building wouldn't be a very good idea. The fill pressure you'd need to get water to the top and pressurized would be much too close to the relief valve's setting. When the water is heated and expanded, your relief valve would pop open.

How we make our feed valves

At Bell & Gossett, we use brass in all our feed valves. We do this because brass is highly resistant to corrosion and widely recognized throughout the plumbing and heating industry as the best material to use at the point where cold feed water and hot system water meet. You see, minerals in the cold feed water come out of solution as its temperature rises. Over the long run, brass handles this situation much better than iron. That's why we chose it for our valves.

We designed a flexible, low-inlet-pressure check valve into all the B&G feed valves. The check valve helps prevent the loss of system pressure should the supply pressure drop below the system pressure. This check valve's design is simple yet extremely effective and is less affected by dirt than, say, ball and flapper-type check valves. Keep in mind, however, that this check valve is not a fail-safe device for backflow prevention.

The lever on the FB-38TU lifts the valve seat so the system can be quickly filled on start-up. That's a real time saver!

Another feature of this valve is the universal, threaded-union tailpiece which has a 1/2" male NPT thread and a 1/2" female sweat connection. Thread it or sweat it, the choice is yours!

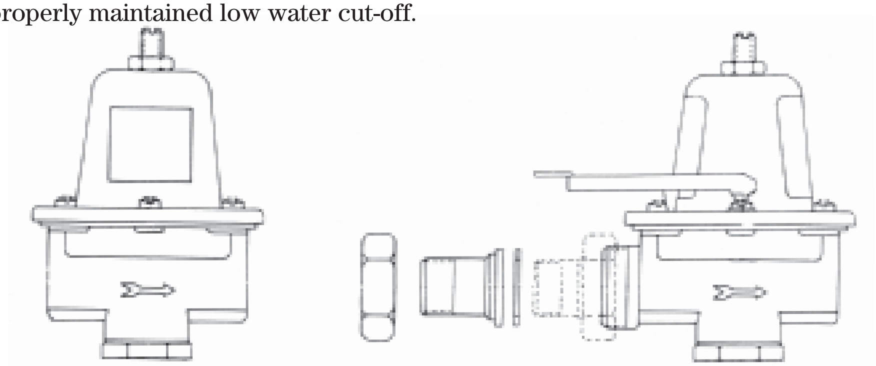
B&G feed valves all feature a cleanable strainer that keeps dirt and sediment from entering the system. You can clean this strainer without removing the valve from the line.

Something you may not know...

Here's an important point. Don't think of a feed valve as a safety device. It's not there to protect the boiler against a low-water condition. The only thing that can effectively protect a hot water boiler from low water is a low water cut-off.

A feed valve's job is to set the initial system pressure. That's it. For safety's sake, you should close the supply valve to the feeder once the system pressure is established. This is important because a feed valve that's left open can mask a system leak. Systems leaks that go undetected can lead to air problems and boiler corrosion problems.

Remember, the only sure protection against a low water condition is a properly maintained low water cut-off.



McDonnell & Miller Low Water Cut-Offs for Hot Water Boilers

Contrary to what many are led to believe, low water protection isn't just for steam boilers. Hot water boilers face the same perils of overheating damage if the water line drops too low. Many people don't think of this as often as they should because hot water boilers serve "closed" systems. They think pressure reducing valves are supposed to feed water automatically should a leak develop.

The truth, however, is that a feed valve is no substitute for a low water cut-off and should be closed once the initial system pressure is established. A concealed pipe can corrode and spring a leak. Relief valves can pop and dump water at a great rate.

A low water cut-off is the only sure way of protecting a hot water boiler from sudden loss of water. The ASME boiler code recognizes this by requiring all hot water boilers with input ratings equal to or greater than 400,000 BTU/HR have low water fuel cut-off devices. Both the International Mechanical Code and

International Residential Code, on which many local codes are based, mandate the use of low water cut-offs on all hot water and steam boilers. **Keep in mind that it is ultimately your local codes and your local inspector that will make the final determination on low water cut-off requirements.**

Most residential hot water boilers are shipped from the boiler manufacturer without a low water cut-off device. Therefore, it's up to the contractor to make the decision to install such a device. Remember that you'll be at the mercy of your local inspector, and different inspectors often interpret applicable codes in different ways.

Because of their comparatively low initial cost and ease of installation, the probe-style low water cut-offs are far more commonly used on residential hot water boilers than the float-style units. When installing a probe-style cut-off always install it above the boiler and be sure there are no isolation valves between the boiler and the cut-off device. It's also important for the probe to be positioned so the tip is far enough into the pipe to minimize the potential for it to be caught in an air pocket, but not far enough in that it contacts the pipe wall. As with all products, be sure to follow the manufacturer's installation instructions.

Air Separation

Circulators move water around a hydronic system pretty quickly. In many cases, water is whipping through the pipes at speeds up to four feet per second! Think of it. Water is in and out of a 12-foot-wide room in just three seconds.

And you know there's more to that flow than just water - there's also air. Air is a problem because your customer can hear it pinging around in the system. No one likes to live with noisy radiators. Noisy radiators lead to callbacks for you.

To make matters worse, this air usually gets trapped in the radiators out at the far ends of the system where it often stops the flow of heat entirely. No one likes to live with cold radiators, so you get another callback.

Where does the air come from? It's in the cold water when you first fill the system. It's dissolved in solution, and cold water holds a lot more air than hot water. When you heat the water, the air comes out of solution and starts to whip around the system like BBs. If you vent the air, the system pressure will drop. You'll have to add more cold water to bring the pressure back up to its normal level, and when you do, you'll be letting even more air into the system.

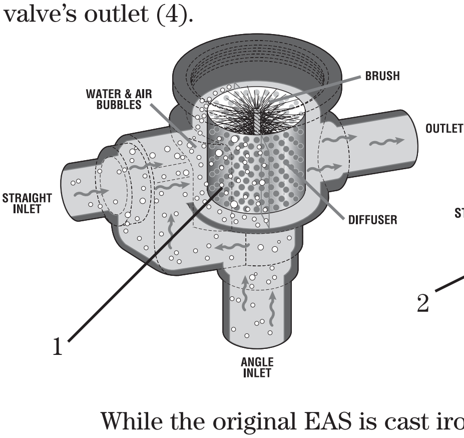
But this doesn't have to be a big problem. All you have to do is catch the air before it has a chance to get into the system. You may be asking yourself, "Won't an automatic air vent remove the system air?" No, not all of it. Automatic air vents installed at high points in the system will remove the large air bubbles that migrate to the top of the system, but they can't effectively remove entrained air bubbles from the high-speed flow we see in modern hydronic systems. You have to snatch those bubbles out of the flow. That's exactly what an air separator does.

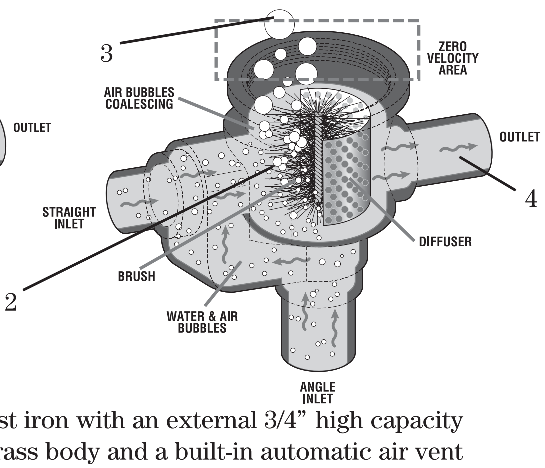
Putting 50 years of air separation experience to work

Bell & Gossett has managed system air for over half a century. You might even say we were the pioneers of air control.We've learned a lot over the years, and we have a full line of air separators to prove it. The EAS and EASB-JR are two of our most sophisticated air separators designed for residential and light commercial applications. Let's take a look at each, starting with the EAS.
Over time, the EAS, or Enhanced Air Separator, removes over 99% of all system air, including microbubbles. When we say over time, we mean that after the water passes through the EAS several times, over 99% of the air is removed. You see, contrary to popular belief, air separators don't remove all of the system air in one pass. They are designed for multiple-pass systems, and they all require the system water to pass through the unit multiple times for optimum efficiency. The more air you get out in the first pass, though, the better off the system's going to be. The EAS has supreme first pass efficiency. That's important because less air traveling through the system means less noise, better heat transfer capabilities, and a happier customer. It also means less callbacks for you.

Correct placement of the air separator in the system can also prevent callbacks. Air wants to come out of solution where the temperature is highest and the pressure is lowest. In a typical heating system, that's after the boiler and before the circulator. If you happen to come across one of the packaged boilers with the circulator pumping into the boiler, you'll want to install the separator after the boiler. In those situations, though, don't install the diaphragm tank on the tank mount underneath the air separator. The circulator must always pump away from the tank for reasons explained in the back of this booklet. In these instances, it's best to install the diaphragm tank before the circulator on the return.

Now, let's get back to the EAS and how it works. Take a look at the illustrations below. You'll see that the EAS contains a wire brush-like element (1) inside the body for the air to cling to (2) as the fluid passes through the valve. This trapped air then rises (3) through a baffle (not pictured) to the air vent at the top of the unit where it's released. The fluid, less air, then exits through the valve's outlet (4).



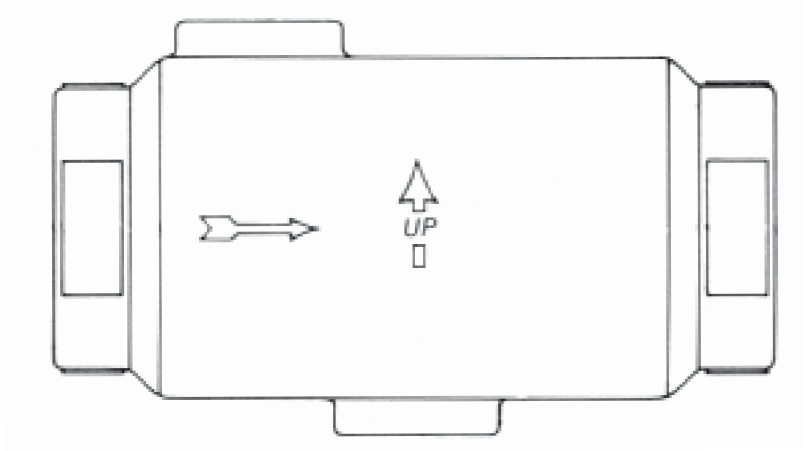


While the original EAS is cast iron with an external 3/4" high capacity air vent, the newer EASB-JR has a brass body and a built-in automatic air vent on top. The way the two devices work, though, is very similar. As fluid enters the EASB-JR, the velocity is decreased creating a low pressure area. The small bubbles are released from the fluid and then collect on the coalescing medium. As the bubbles coalesce, they rise to the top of the air separator where they are released through the automatic air vent. That 1/2" tapping that you see on the bottom of the EASB-JR is there just in case you want to install the B&G diaphragm expansion tank there instead of elsewhere in the system.

Whatever your requirements - cast iron or brass, sweat or NPT, straight or angle installation -- the EAS & EASB-JR air separators have got you covered.

IAS also stands for "It ain't the same!"

IAS stands for Inline Air Separator. The IAS uses air's natural buoyancy to get the job done, so it requires no moving parts. It has two chambers, and it's a bit wider than the pipe it serves. We've separated the two chambers with an orifice, and therein lies the secret to the IAS's great performance. An orifice is a hole



that's a bit smaller than the chamber itself. Air-laden water flows through the pipe and enters the "wide space in the road" — the IAS. Naturally, as the water widens out in the IAS, it also slows down. That slowing motion releases the air bubbles in the same way a slowing river current releases floating debris.

The air bubbles quickly float to the top of the first chamber and get trapped by the wall of iron that makes up the orifice. Once captured, the IAS vents the air out of the system through a field-installed automatic air vent or up into a plain steel compression tank. The water (now minus most of the air) passes through the orifice and flows to the radiators. Since the IAS snatches the air out of the flow just as it leaves the boiler, the air doesn't get a chance to create problems out in the system.

We use the second chamber in the IAS to make sure a whirlpool doesn't form in the center of the orifice. Going from a wide space to a narrow space and then back again to a wide space creates a "quiet zone" just above the inlet to the orifice. That second chamber on the outlet side of the orifice keeps the air from being sucked into the system. Beautifully simple, isn't it?

"Scoops" are different

Other types of air separators use an inclined plane to remove air. These are commonly called "air scoops." We decided to use the orifice design instead of the "scoop" design for the IAS after extensive testing in our research lab convinced us that an orifice removes more air on each pass. We figured the more air we could catch the better. Makes sense, doesn't it? (That's why IAS also stands for "It Ain't the Same!")

The top tapping on the 1-1/2" through 3" IAS air separators is 3/4". We decided on a 3/4" tapping for the larger IAS separators instead of the 1/8" tapping you'll find on the "scoops" because we wanted you to have as many options as possible. With a 3/4" tapping, you can use either a residential or commercial type of air vent. It's your choice.

And because the tapping is 3/4" and not 1/8", you can also use the larger IAS air separators with a steel compression tank if you wish. Many times, those tanks are there in the basement already. They're free! Why not take advantage of them? We figure the choice should be yours.

Like the EASB-JR, the IAS has a 1/2" bottom tapping. You can use this tapping to connect the diaphragm tank (if you're using a diaphragm tank).

Any hot water heating system can be made better with an air separator like the EAS, EASB-JR, or IAS. They all do a fine job, and they won't cost you a fortune.

Compression and Expansion Tanks

Now let's see how tanks work.

When you fill a closed hydronic system with cold water and then heat it to a high limit, you wind up with about five percent more water than you started with. That's because water, like most everything else, will expand when heated.

Since you already have the system completely filled with water, you're going to be in trouble if you don't have a tank to accept that "extra" water. Without a tank, the relief valve will probably pop every time the burner comes on.

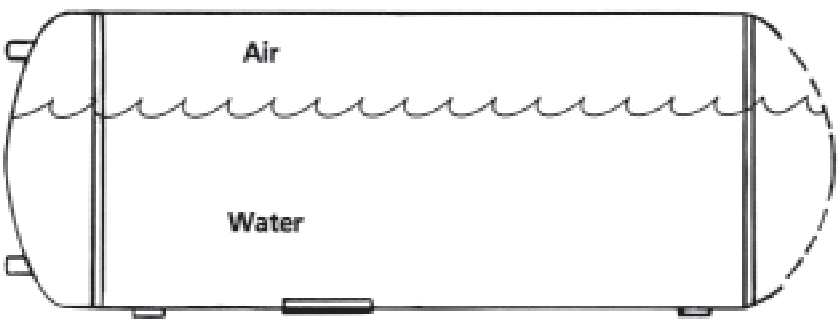
You can't compress water, but you can compress air. And once you trap a pocket of air in a tank, you can use it to give that "extra" water something to squeeze. The air in the tank becomes a pneumatic spring. It takes up the slack whenever the water starts to bulge.

There are two kinds of tanks: the closed steel compression tank and the expansion tank. Let's take a look at them.

Closed steel compression tanks

A closed steel compression tank has no moving parts. Normally, it starts out with a cold fill of about 2/3 water and 1/3 air. As the system water expands, that "extra" water moves into the tank and squeezes the air cushion.

The now-compressed air creates an increase in system pressure. You can see this on the boiler's pressure gauge. Keep in mind, though, that this pressure increase has nothing to do with the pressure the circulator develops or the static pressure the column of system water exerts. This pressure is created solely by the expanding water. It's a pressure created by a rise in temperature. The higher you raise the water's temperature, the more it will expand. The more the water expands, the greater the increase in pressure will be. Of course, you have to take this into consideration when you select the tank, but if you do a good job of



sizing, the pressure will usually rise only a pound or so by the time the system reaches its high-limit temperature.

As the system cools down on its off cycle, the water shrinks and allows the air in the tank to expand back to its original volume. You'll see this as a drop in system pressure on the boiler's pressure gauge.

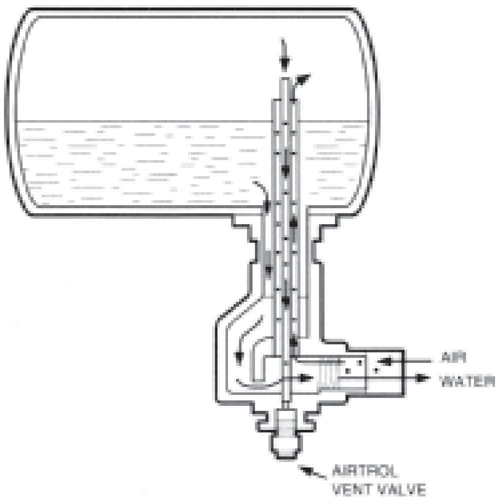
So what you're really seeing on the pressure gauge as the system heats and cools is the expansion and contraction of air inside the compression tank. How much of a change in pressure you'll get depends on how big an air cushion the water has to push against. In other words, the size of the tank.

This also explains why the relief valve pops when you lose your air cushion in a steel tank. Without an air cushion, there's no longer anything for the expanding water to squeeze.

A fitting that prevents waterlogging

If the steel compression tank is directly connected into the system, air will eventually leave the tank and work its way up into the radiators. That's because the system water can reabsorb the tank's air cushion and move it (by gravity circulation) out of the tank and back into the system.

B&G's Airtrol Tank Fittings prevent the air from leaving steel compression tanks by creating a gravity-flow "check valve" between the tank and the system. Airtrol Tank Fittings solve the escaping-air problem once and for all because they stop gravity circulation.

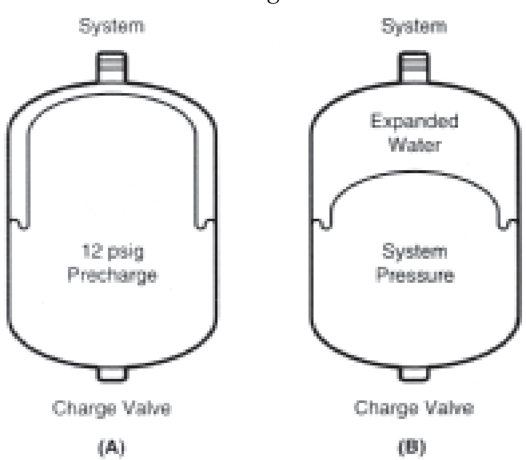


Every steel tank can be made better with the addition of an Airtrol Tank Fitting. We know of systems with steel tanks that were installed decades ago. They've never lost their original air cushion! Thanks to the Airtrol Tank Fittings, you'll never hear of an air-related complaint on these jobs.

Expansion tanks

There are two types of expansion tanks – the diaphragm tank and the bladder tank.

Diaphragm tanks separate the air from the water using a flexible rubber membrane or diaphragm. The bladder tank uses a flexible rubber bag or bladder. Both tanks serve the same purpose as steel compression tanks, but the expansion tanks are generally smaller because a portion of the tank is pre-charged with compressed air. Because bladder tanks are typically found on commercial installations and diaphragm tanks on residential installations., we'll continue discussing diaphragm tanks and leave the commercial discussion for another time.



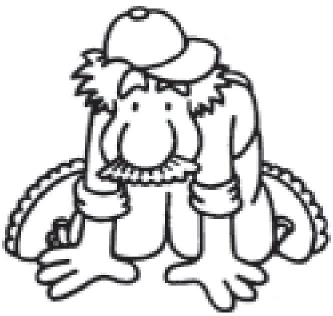
When you start out, the air side of the diaphragm is fully expanded and flush against the inside of the tank. But when you connect the tank to the system and feed water into the other side of the diaphragm, the water's pressure pushes back against the compressed air and squeezes it like a balloon. As long as the tank is in good working order, the water and air never touch each other. Should the diaphragm fail, however, the tank will lose its air cushion and the relief valve will almost surely pop on the next firing cycle.

Most residential diaphragm tanks are pre-charged to 12 psi to match the fill-pressure needs of a typical two-story house. When the feed-water pressure reaches 12 psi, the system will be filled to the top floor and will be under several pounds of pressure. At that point, no more water will enter the system because the pressures on both sides of the diaphragm will be equal. It pays to check the air pressure in a diaphragm tank before you install it, because some of the air may have escaped during shipment and storage.

Pump it up!

Naturally, if you have a building taller than two stories, you'll have to pump up the air side of the diaphragm to match the feed-water pressure you'll be using to get water up to the top and pressurized. This is very important. If you don't pump up the tank to match the fill pressure, the relief valve will probably pop. This happens because the water pressure, being greater than the air pressure, will have pushed the diaphragm all the way back before the water begins to expand. When the burner fires, the expanding water has nowhere to go.

You can't check the air pressure in a diaphragm tank when it's connected to the system because the water pressure on the other side of the diaphragm will compress the air and give you a false reading. To get an accurate reading, you first have to disconnect the tank from the system.

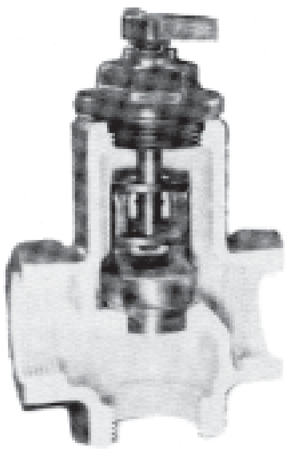


The Flo-Control Valve

The principle that made gravity hot water heat work (the fact that hot water will rise because it weighs less than cold water) is the very thing Flo-Control valves are designed to stop.

In the days of gravity heat, circulators weren't available, so installers used large pipes and let the water "turn" slowly on its own. But nowadays, heating pipes are much smaller and every hot water system has a circulator.

The only time hot water should leave a modern boiler is when a thermostat calls for the circulator to come on. If hot water is unchecked and allowed to "gravity circulate" out of the boiler when the circulator is off, the zone will overheat, and you'll have a callback. So when you zone with circulators, you'll use Flo-Control valves to keep the hot water in the boiler. Let's take a look inside one.



How it works

This is B&G's SA value, "SA" stands for "straight or angle" which means, for piping convenience, you can use either the bottom or side tapping of the Flo-Control valve as an inlet. Naturally, there's only one outlet.

As you can see, there's a weight inside the Flo-Control valve. It's made of bronze, and it rides up on the valve stem whenever the circulator operates. When the circulator shuts off, the bronze weight drops back down onto the seat. The weight prevents gravity circulation when the zone is off.

To work, the Flo-Control valve must always be installed with the stem pointed toward the ceiling. You should always install the Flo-Control valve in the supply piping because the system water is hottest at this point. There are times, however, when you may need a second Flo-Control valve on the return side of the boiler because, believe it or not, gravity circulation can occur in a single pipe! It doesn't need a complete loop.

The hot and cold water just flow past each other in the same pipe. You'll usually notice this "back end" gravity circulation if there's a radiator directly above the boiler on the return side. Adding a second Flo-Control valve to the return side of the zone piping will solve the problem every time.

If you turn the stem handle at the top of the Flo-Control valve counter-clockwise, you'll manually lift the bronze weight from its seat. This will effectively take the Flo-Control valve "out of the loop" and allow the boiler to gravity circulate. The only time you'd want to do this, however, is if the circulator failed. Turning the stem handle and lifting the weight will give the folks some heat during the time the circulator is down, but this is essentially a home owner feature because, let's face it, if you're there on the service call, you're usually going to fix the circulator, not bypass the Flo-Control valve.

Turning the stem handle has no effect on the system other than to allow gravity circulation to take place. In other words, that stem handle won't help you balance the system's flow rate or direct the flow in any other way. Its only function is to raise and lower the bronze weight.

We mention this because we've seen guys try to make the water flow a certain way by pointing the stem in this direction or that direction. That's not what it does.

"Weightless" flow control

For those installations where the traditional weighted Flo-Control valve just won't work, Bell & Gossett now manufactures the Hydrotrol™ Flow Control Valve. The most important feature of this new valve is its design; the benefit - versatility. The Hydrotrol prevents zones from overheating due to gravity circulation just like a traditional flow control valve, but it works without a weight. When the circulator is operating, the flow of water forces the spring-loaded seat inside the Hydrotrol to open, and the water flows right through the valve. When the circulator shuts off and is no longer moving the water, the seat closes. Because the Hydrotrol is spring-loaded it can be installed in the horizontal or vertical orientation to discharge in any direction. No need to install an isolation valve, either; the elastomer seal in the Hydrotrol provides positive check. The 1/2 turn knob manually opens the valve for system draining or valve bypass. It's available in 3/4", 1" and 1-1/4" sizes, and straight-angle configuration. Versatility, convenience, simplicity – Hydrotrol.

The 3-in-1 Check-Trol™

Here at Bell & Gossett we're all about offering products that save you time and money. That's why we've designed a combination flow control valve, isolation valve and companion flange, complete with capscrews and nuts – all for about the same amount of money you'd spend on the flow control valve alone. We call it Check-Trol. You'll call it handy! The isolation or ball valve, when closed, allows the circulator to be removed from the system without first draining the system. There's an internal spring check that acts as the flow control valve and prevents gravity circulation. The companion flange is free floating so it can be rotated in any direction. This makes it easier to align the bolt holes of the flanges when installing to the piping system. The Check-Trol is installed on the circulator discharge, and it provides all of the features of a flow control valve, isolation valve and companion flange, all with minimal pressure drop and space requirements.

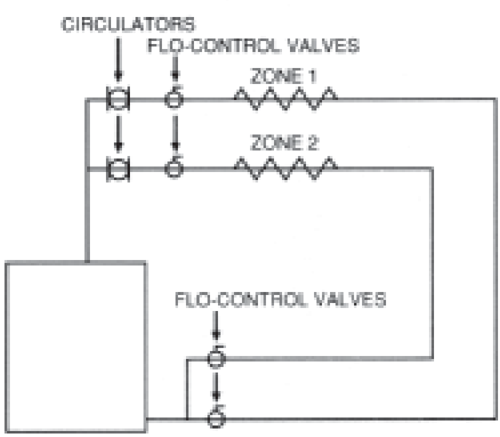
A hydronic brain teaser

Here's a problem for you to consider.

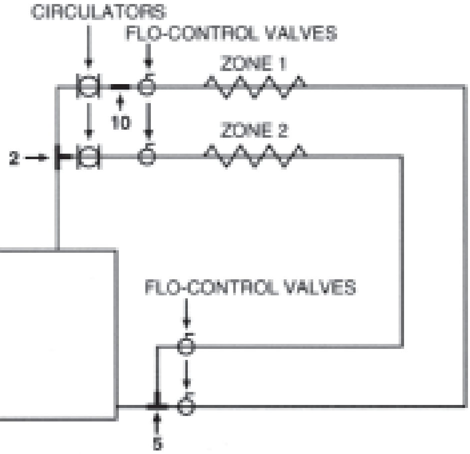
Zone #1 is calling for heat, and Zone #2 is off. The last radiator on Zone #2 is getting hot. Can the flow moving past the return tee connecting Zone #1 and Zone #2 be "pulling" water down from Zone #2?

Give it some thought.

The answer is no, it can't! The reason is simply this. High pressure must travel toward low pressure, and the circulator is " strongest" at its discharge and "weakest" at its suction. For these reasons, it's impossible for the "Zone #1" circulator to "suck" water down out of "Zone #2."



Here, let's assign some numbers to the zone to show the circulator's relative strength at different places in the zone.

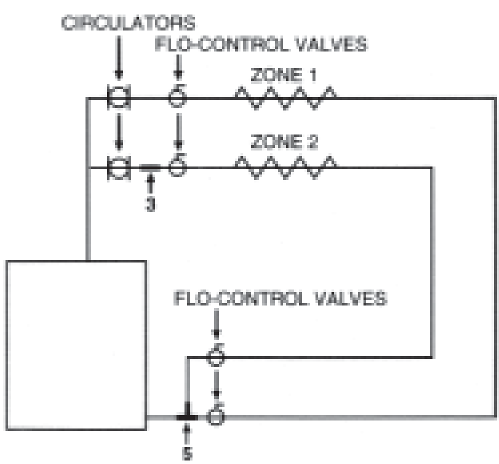


Let's say the strength of the circulator at its discharge flange is "10." As water flows, friction eats up some of the circulator's power. By the time it reaches the return tee, the circulator's strength is down to "5." Now the water flows through the boiler and out the supply header. Its strength at the supply tee leading to the two zones is down to "2."

Do you see what we're getting at? For water to be "sucked" out of Zone #2's return by Zone #1's circulator, water would have to enter Zone #2's supply at the same time.

But look at the relative "strength" of the pump at Zone #2's supply and return tapping. It's stronger at the return than it is at the supply. So how could water flow that way? Water can't move from low pressure to high pressure, can it? Of course not. And that's how you can know for sure that Zone #1's circulator isn't "sucking" water down from Zone #2.

So why is the radiator getting hot? It's because Zone #2's Flo-Control valve has dirt under its seat. Watch.



Can you see it? Some of the return water from Zone #1 is moving backwards through Zone #2. How do you solve the problem? Just unscrew the top of the Flo-Control valve and clean it out. Easy!

By the way, this is one of the reasons why it pays to flush all hydronic systems after you install new equipment. Most installers rarely do this, but that little bit of extra effort can save you a lot of nagging callbacks.

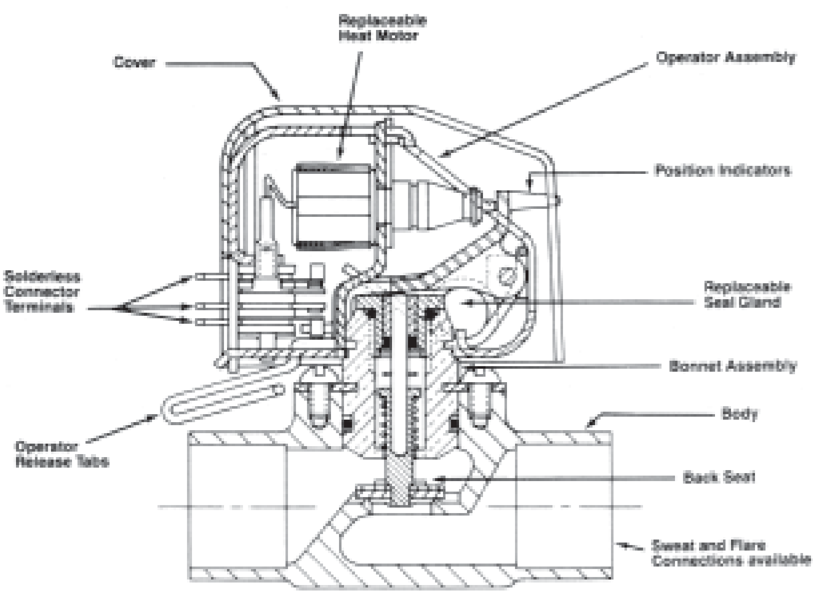
Let's take a look at some zone valves.

Electric Zone Valves

Another way to zone a hot water system is to use electric zone valves with a single circulator. The zone valve takes the place of the Flo-Control valve. Each zone valve acts as a "Gatekeeper" to the zone it serves. The circulator provides the water, and the zone valve allows that water to either pass or not pass.

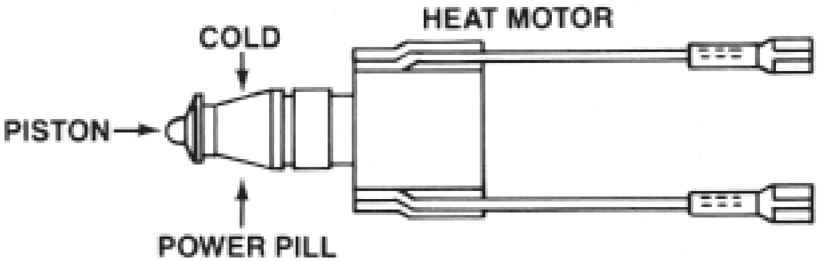
The operating sequence

To give you an understanding of how electric zone valves work, let's take a look inside B&G's Comfort-Trol valve's operator.

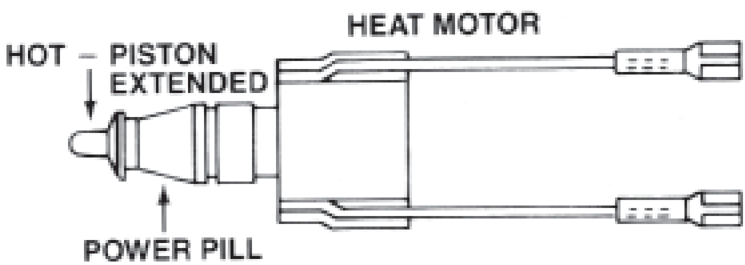


First, the room thermostat calls for heat by sending an electrical “Go” signal to the zone valve’s operator. Inside the operator, the electricity flows through a normally closed switch and around a tightly wound coil called a heat motor. This wire has high resistance, so when the current flows through it, you get heat.

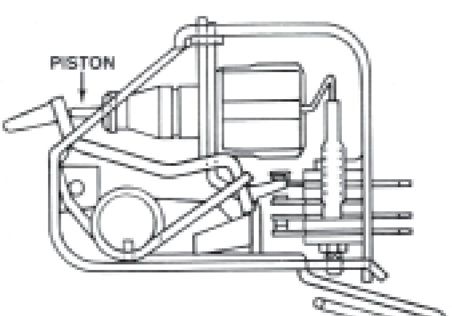
And heat is exactly what you want because the heat motor surrounds this bullet-like device called a power pill.



The power pill is filled with a temperature sensitive wax that expands when the heat from the heat motor hits it. As the wax expands, it pushes a piston out of the power pill.



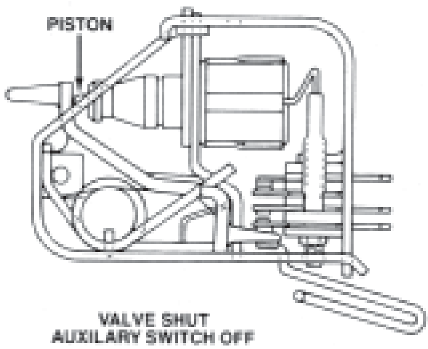
The piston pushes against the spring-loaded lever that normally holds the valve closed. This action lifts the valve disc off its seat and opens Comfort-Trol’s water valve. Water now has access to the zone. But nothing is flowing because the circulator hasn’t yet been called on by Comfort-Trol’s operator. That’s about to happen, though, because the piston will keep pushing the lever forward until it trips an end switch.



VALVE OPEN
AUXILARY SWITCH CLOSED

The end switch makes a connection (through a relay) back to the circulator. The circulator instantly comes on and moves water through the Comfort-Trol water valve and out to the zone. In systems without tankless coils or side-arm heaters, the end switch, working through the relay, would fire the burner at the same time it starts the circulator.

Meanwhile, back at the Comfort-Trol operator, we have to have a way to shut the heat motor off, so we let the piston stretch out just a bit further until it breaks the heat motor switch.



That switch cuts power to the heat motor, and almost immediately, the wax in the power pill begins to cool and shrink. Naturally, as that happens, the spring-loaded lever arm pushes the piston back into the power pill. The circulator, however, is still running while this is going on because the end switch is still closed. That means Comfort-Trol's water valve is still open, and hot water is still flowing out to the zone.

The piston slides back a bit, just enough to allow that switch to close and send power to the heat motor again. The piston then goes back out again, the circulator continues to run, and the zone continues to get heat. Comfort-Trol's piston keeps sliding back and forth as long as the thermostat calls for heat.

Taking control of water hammer noise

When the thermostat is finally satisfied, the power to the Comfort-Trol valve is cut. As the power pill cools, the piston is forced back by the spring-loaded lever arm. This breaks the end switch, sending a "Stop" signal to the circulator. Then the spring-loaded lever gently seats the Comfort-Trol valve, and water stops flowing through the zone. The slow closing action of the valve lessens the chance for water hammer shock when the valve finally seats.

Water hammer is a common problem with some electric zone valves that close too quickly. If two zone valves are calling at the same time and one shuts off, the circulator will continue to run. The valve now has the burden of seating against flowing water. If the valve can seat slowly, it will not bang. However, if the valve tries to close too quickly, it will hammer like a solenoid valve on a washing machine.

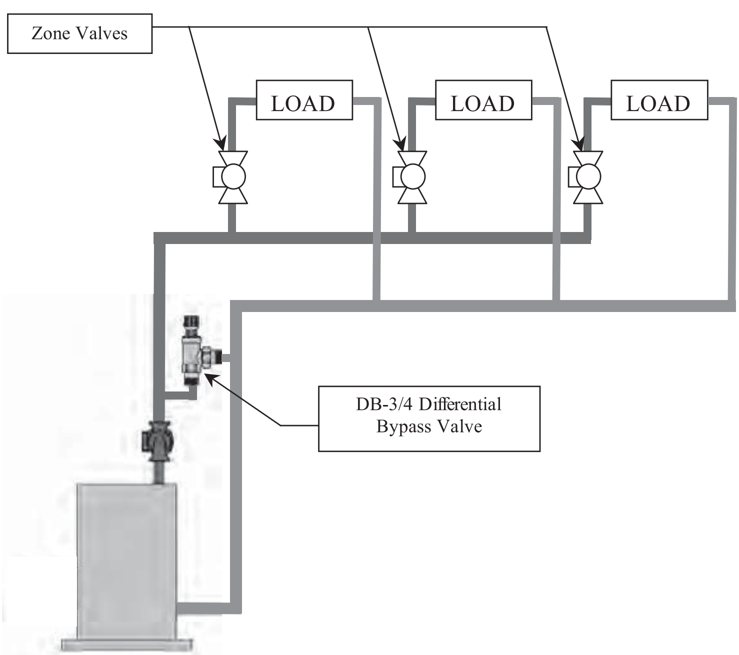
There are other types of zone valves on the market that work a bit differently than the Comfort-Trol. Some, for instance, use clock-type motors to open and close the valve. Others are power-driven open and power-driven closed. We chose the heat motor design for our Comfort-Trol zone valve because we believe this gives you the best combination of small size and quiet operation. We know that zone valves are not always installed in boiler rooms. Often, they're installed inside the baseboard, right in the living space with your customer. Obviously, valve size and noise become very important when the valves are used in places such as this.

We wanted something that would work anywhere you decided to use it. That's why we chose the heat motor design. Comfort-Trol fits where others often can't.

...and velocity noise

If you zone with zone control valves, you've no doubt had to deal with velocity noise caused by excess flow and head. It's annoying, and it makes home-owners very unhappy. The DB-3/4 Differential Bypass Valve can help with that. The DB-3/4 is a spring-loaded valve with 3/4" connections that allows recirculation of excess flow from the system back to the boiler. It's installed near the pump discharge and between the supply and return piping, like you see in the illustration below. Before the valve is put into service, it's adjusted to the setting equal to the design pressure rating of the pump when all zone valves are open.

Now, here's how the valve works. When there's a reduction in demand, say only one zone of three is calling for heat, the two zone valves installed on the zones not calling for heat close. In the meantime, the circulator is moving the same amount of fluid through the system even though only one circuit is calling for heat. As a result, the pump produces a higher head, especially if the pump has a steep curve. The DB-3/4 senses the excess pressure produced by the pump and lifts its spring-loaded seat. This, in turn, opens the valve and provides a detour for the system fluid to return to the boiler.



The Circulator, And How It Moves Water

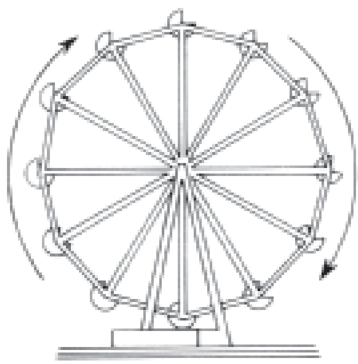
At Bell & Gossett, we make many different types of circulators. Some run at low speeds and are lubricated with oil. Others run at higher speeds and are lubricated by the system water. Some, like the Series 100, have a coupler between the motor and the pump. Others, like our NRF have a motor shaft that's directly connected to the pump.

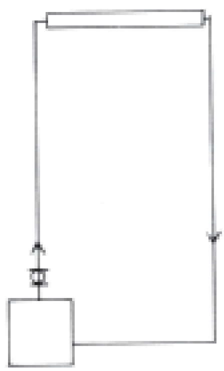
We manufacture a very complete line of circulators, and one might look quite different from another. But they all do essentially the same thing.

Job description...

A circulator's job is to move hot water from the boiler to the radiators, and then return the cooled water for another injection of heat. In other words, it creates a flow on which heat rides like a passenger.

Ever think about how it gets that job done? A lot of installers think the circulator's job is to lift the water to the top of the system. It's not. That job has already been filled by the feed valve. And since the system is already completely filled with water, all the circulator has to do is move it around. It helps to think of a heating system as a Ferris wheel.





When a Ferris wheel turns, the weight going up balances the weight coming down. There's no lifting going on here, there's only turning. That's because everything is in perfect balance. The Ferris wheel's motor doesn't have to do any lifting. All it has to do is overcome the friction in the bearings (and in the air, of course) to set the big wheel in motion.

Now think of a heating system. It's like a big wheel of water, isn't it? Once the feed valve has done its work, there's no lifting involved. The system is completely filled with water. So when the circulator comes on, the weight of the water flowing up is going to be perfectly balanced by the weight of the water flowing down.

And like the motor on a Ferris wheel, all the circulator has to do is overcome the friction to set that "wheel of water" in motion. In this case, the friction is caused by the water as it rubs against the inside of the pipe and goes through valves, fittings and other system components. We call this friction "Pressure Drop." If the circulator can overcome the system's pressure drop, water will flow.

"Pump head" is not height!

We use the term "Pump Head" to describe the force the circulator develops to overcome pressure drop. When we work with closed hot water heating systems, "Pump Head" has nothing to do with the height of the building. It has only to do with the circulator's ability to overcome friction. That's because the system is completely filled with water. Height, as far as the circulator is concerned, doesn't exist. The circulator doesn't know (or care!) if the building is

100 feet high and ten feet wide, or ten feet high and 100 feet wide. All it knows is friction.

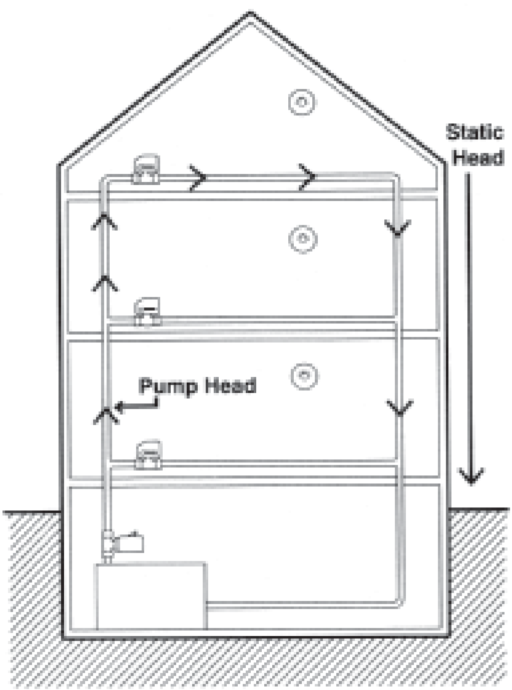
Another thing you have to understand is that the force the circulator creates, the Pump-Head pressure, has nothing to do with the static pressure created by the column of water in the building.

The circulator doesn't care how high or wide the building is.

Pump pressure and static pressure

Remember we talked about static pressure when we looked at feed valves? Well, the pressure created by a circulator and the pressure created by the feed valve are totally independent of each other.

Static pressure has nothing to do with the number of fittings and valves or the width of the building's piping network. Static pressure has only to do with gravity, and the weight of the column of water.



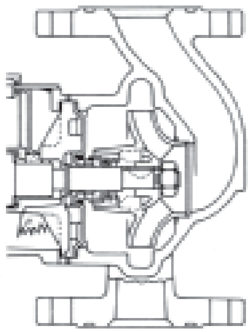
Static Head has to do with height. Pump Head has to do with friction. Don't confuse the two!

"Pump head," on the other hand, has a lot to do with the number of fittings or valves and the size of the building's piping network. But it has nothing to do with gravity or the fill pressure of the system.

Take a moment now to let that sink in. Get it straight in your mind, because it's one of the most-often-confused points in hot water heating. Static pressure and pump pressure are totally independent forces. You can add them together, but they're created by two different things. Don't mix them up.

How circulators work in closed systems

Okay, now let's take a look inside the business end of a circulator and see if we can figure out how it manages to create this force that's capable of turning this big water wheel we call a heating system.

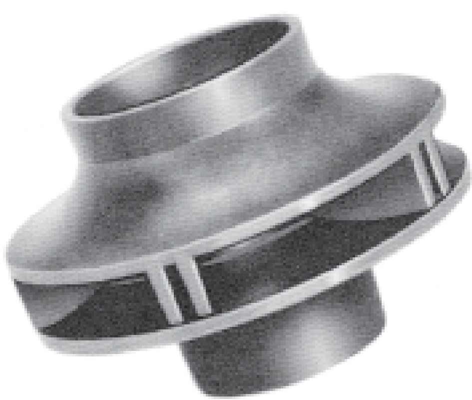


The circulator, like the rest of the closed heating system, is always filled with water. There's no way it can ever empty itself of water when it's running. All it can hope to do is toss out what's currently inside of itself.

But as soon as it tosses that water out, more water comes flowing in. It's operating in a sealed loop, so the supply of water is unlimited.

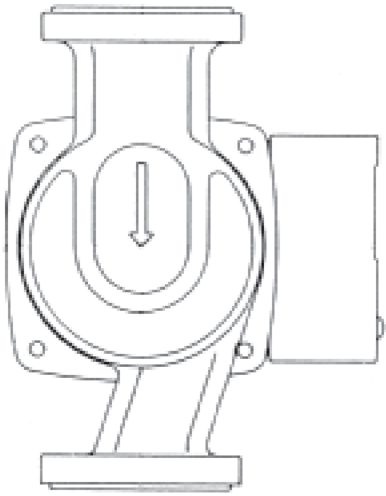
The rotating part of the circulator is a water wheel we call an "impeller." An impeller uses centrifugal force to create velocity and move water. The pump shaft passes through the dead center of the impeller's back end and comes out in front through an opening that's known as the "eye." The "eye" of an impeller is similar to the "eye" of a hurricane. Everything swirls away from that central "eye" because of centrifugal force.

The circulator's impeller has curved vanes that direct the water flow.



These vanes fling the centrifugally forced water away from the impeller's eye and toward the smooth channel of the pump's body. We call that pump body a "volute" because of its unique shape.

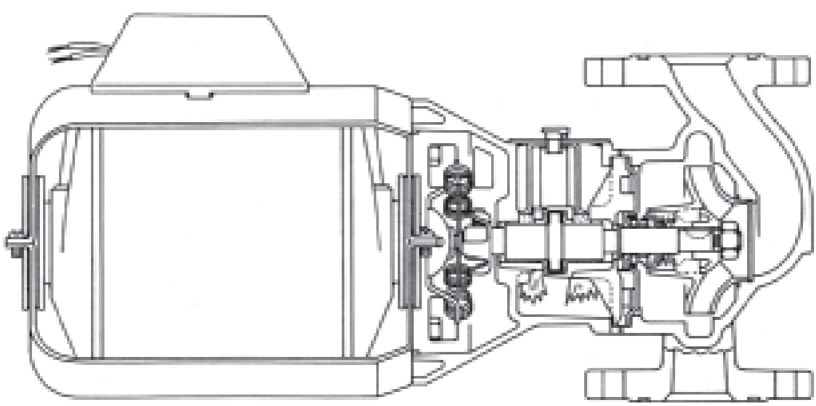
The volute's smooth channel accepts the water from the impeller and directs it toward the outlet of the circulator. But before the water can leave the circulator, it has to pass through an exit channel that's significantly smaller than the entrance channel.



The water has to squeeze through this smaller opening to get out of the volute. The effect you get is similar to what happens when you put your thumb over the end of a garden hose. The velocity increases, doesn't it? Well, that velocity is the force that moves the water around the system. It's the force that overcomes the system's pressure drop.

Remember, there's no lifting going on here, no pulling or pushing either. Circulators turn the water, just like a big Ferris wheel.

Series 100— The industry's workhorse



The Series 100 circulator has a bearing assembly that holds the pump shaft. The shaft spins at 1,750 rpm on two, quiet-operating sleeve bearings. You should always use SAE-20 non-detergent oil on sleeve bearings. Don't use detergent oil because detergent builds up over time, and since it has no lubricating properties, it can lead to bearing failure.

The mechanical seal in the Series 100 is made from carbon and a special alumina-oxide ceramic. We use this ceramic because it can take a wider range of pH than the common ceramics used in some pump seals. Ideally, the system water should have a pH no lower than 7 and no higher than 9. Depending on the quality of the water and the type of chemicals used in the system, however, the pH can change. This is a commonly overlooked problem that often leads to system corrosion problems and circulator seal failure. We've engineered our seal to last under these variable conditions, but it pays to check the water's pH when you're troubleshooting a system.

We use a wool wicking to draw oil up onto the sleeve bearings. The capillary action of the wool brings the oil to the bearing, and leaves any sediment behind in the reservoir.

If you over-oil the bearing assembly, the excess oil will simply overflow through the bearing assembly's weep-hole. The weep-hole is important, and you should never plug it. If you do, any dirt or sediment in the oil will find its way into the bearings and shorten their life.

We design our own motors for the Series 100. We use a thick shaft, heavy rotor and over-sized, dirt-resistant switches for long life. They, too, have sleeve-bearings so they're also very quiet. We cradle our motors in oil-resistant motor mounts to make sure the slight purr of the motor doesn't make its way into the system piping.

We stamp our couplers out of steel for good balance and quiet operation, and we dip the ends in a special epoxy to lessen the possibility of wear between the coupler's yoke and springs.

Those are just a few of the features that continue to make the Series 100 one of the most popular circulators in America.

Maintenance-Free Circulators

Unlike the oil-lubricated Series 100, our wet rotor circulators are maintenance – free because they're lubricated by system water. No more oiling! They'll provide years of trouble-free operation.

Our Red Fox Series (NRF) wet rotor circulators are compact. The smallest of the series is less than 10 pounds and can fit in one hand. Their compact size makes them ideal for zoning or injection pumping in radiant panel hot water heating systems. Offering a wide range of hydraulic performance, the larger NRF-36 and NRF-45 are available with three speed motors for flexibility and are equally suitable in a residential or a small commercial heating system. All NRF wet rotors feature the B&G Duraglide Bearing System, carbon bearings, stainless steel face plate and rotor shaft, and a self-cleaning particle shield that protects the shaft and bearings from system start-up debris. All of these features combined add up to a reliable, long lasting and more efficient pump. The standard NRF is cast iron, but for potable water applications, it's also available in stainless steel and all bronze construction. For your convenience, the stainless steel and all bronze NRF's are available with flanged, union or sweat connections.

The series PL line of maintenance-free circulators is designed for long life, rugged conditions and exceptional performance. Its dry motor design is less susceptible to friction and drag, making it 25% more efficient than a wet rotor circulator. The advanced close-coupled design, permanently oil-lubricated bearings and durable carbon/silicon carbide seals work together to handle high temps for long periods of time with a minimum of wear. The PL pumps can easily handle dirty water conditions making them a superior alternative to the larger wet rotor pumps for use on cast iron systems with high levels of iron oxide or systems with high mineral content.

For those applications where there is overlap in performance between the NRF and the PL, use the NRF for applications that are close to quiet living spaces, overhead in an office building, single family or multi-unit residential, etc. The PL design with mechanical seal and permanently lubricated bearings is better suited for dirty water systems or those with low NPSHA, such as wood burning boilers.

So depending on your system needs, Bell & Gossett has a circulator to suit your needs.

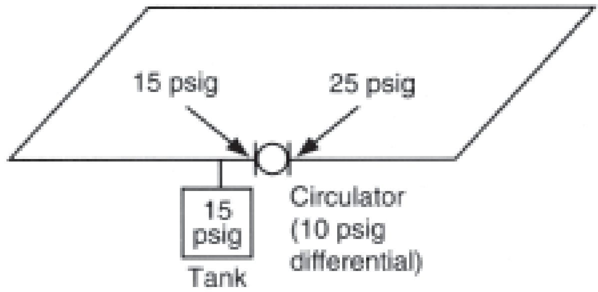
One last word about circulators before we move on. When installing any circulator, be aware of water temperatures. All of our circulators operate well in water that's less than 225˚F. You won't usually find water this hot in a hydronic system, but it can become a problem if you're using the circulator to pump water out of a steam boiler for a hot water zone.

The Point of No Pressure Change

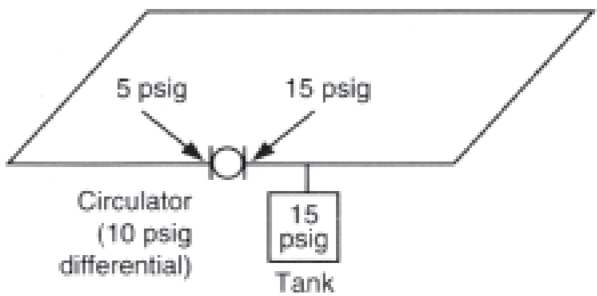
When a circulator operates in a closed hydronic system, it creates a pressure differential. The pressure at the discharge will always be greater than the pressure at the suction. But because the pump operates in a closed loop, the discharge pressure may not necessarily exceed the system's static fill pressure.

The circulator uses the compression tank as its "point of no pressure change." This term, coined in the early 1960s by B&G, refers to the fact that the circulator can never affect the pressure that's found at the point where the compression tank attaches to the system. The circulator has to produce a pressure differential, but whether or not that pressure appears as an increase or a decrease from the system's static pressure doesn't matter as far as the circulator is concerned.

If you pump away from the compression tank, the circulator's pressure will be added to the system's static fill pressure. This will give you a net rise in system pressure.



However, if you have the circulator pumping toward the compression tank, it won't be able to show its discharge pressure as an increase. Instead, it will show it as a decrease at its suction side. Like this.



What's in it for you?

By pumping toward the system and away from the compression tank, you will be increasing the overall pressure in the system. This makes the job of air removal much easier and eliminates many of the common air-related noises that often lead to callbacks for you.

However, if you pump toward the compression tank, the overall system pressure will drop whenever the circulator starts. This sudden drop in pressure will release dissolved air from the system water, creating noise and air-binding problems.

That's why it pays to have the circulator pumping away from the compression tank, no matter what size the system is. What B&G said in the early 1960s still applies today. Many contractors have profited by these teachings, saving time and money on every job they've installed.

Thanks

We thank you for spending this time with us. We hope you had some fun! We've been working with customers on tough problems for many years. We've learned a lot, and we're always willing to share our knowledge with you. If you have a tough question, we want you to know you can depend on your Bell & Gossett rep for the answers. Just give us a call, and we'll be there.

We want to thank you as well for the continuing support you give us by using Bell & Gossett products. We realize you have a wide choice in the hydronic equipment that's available today, and we want you to know we will continue to work hard to earn your trust.

Xylem |ˈzīləm|

1) The tissue in plants that brings water upward from the roots;
2) a leading global water technology company.

We're 12,500 people unified in a common purpose: creating innovative solutions to meet our world's water needs. Developing new technologies that will improve the way water is used, conserved, and re-used in the future is central to our work. We move, treat, analyze, and return water to the environment, and we help people use water efficiently, in their homes, buildings, factories and farms. In more than 150 countries, we have strong, long-standing relationships with customers who know us for our powerful combination of leading product brands and applications expertise, backed by a legacy of innovation.

For more information on how Xylem can help you, go to www.xyleminc.com

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