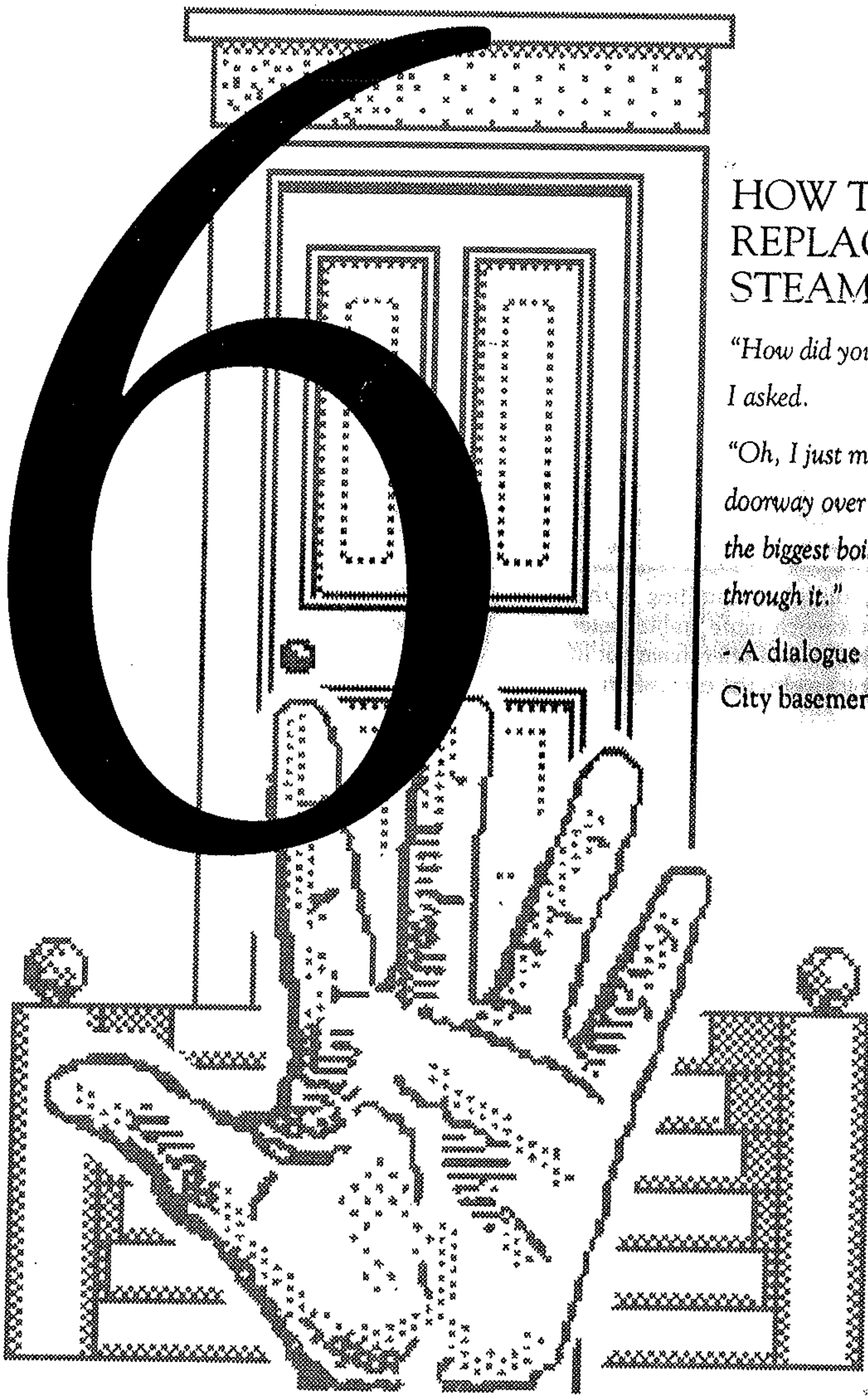
CHAPTER 6



HOW TO SIZE REPLACEMENT STEAM BOILERS

"How did you size this boiler?" I asked.

"Oh, I just measured that doorway over there and ordered the biggest boiler that would fit through it."

- A dialogue in a New York City basement, 1989

I *just ordered the biggest boiler that would fit through that door...*" Don't you love it! That's known as the "Doorway Method" of boiler sizing. It's used every now and then.

There are other, more-widely-used methods. For instance, there's the "Label Method." That's where you read the label on the old boiler and then give the customer the exact same thing. Or maybe you bump it up a section, just for good measure.

The theory assumes that if this size boiler worked then, it should also work now. It makes the assumption that the guy before you was an infallible heating genius, and that the world never changes.

Then there's the "*Looksalotlike Method.*" This is similar to the "Label Method." With "*Looksalotlike*," you say to yourself, "*This looks a lot like that job I did last year. That one worked reasonably well. I guess I'll use the same boiler for this one.*"

A fellow in Bridgeport, Connecticut taught me what has become my favorite method. He said he knew this old-timer who used to walk across the street from the house (exactly 63 feet), then close his right eye while holding the four fingers of his left hand up at arm's length.

"*Four sections,*" he'd say, if the width of his fingers covered the entire house. If it didn't, he'd add another finger from his right hand.

"*Five sections,*" he'd say. And if that didn't do it, he'd give it another finger - and another section. "*Six sections!*"

This in known as the "Finger Method" of boiler sizing. The guy in Bridgeport told me this method served the old-timer well for many years.

Of such things are legends made.

I think it would be nice if replacement steam boiler sizing was that simple, wouldn't you? Unfortunately, it isn't. So let me talk to you a bit about how to size a replacement steam boiler - and how to stay out of trouble while you're doing it.

Things to Consider

I'll begin by asking you the big question: Suppose you're quoting on a replacement boiler and the home owner tells you he just finished insulating the house, installing new windows and doors and weather-striping every crack and crevice he could find. Does all this good energy-conservation work affect the job you have to do?

The answer is NO! It doesn't. Oh sure, he's done a lot to cut the heat loss of the house and save energy, but believe it or not, the heat loss of the house has absolutely nothing to do with the size of the replacement steam boiler. If you were sizing radiators, heat loss would be a concern. But you're not sizing radiators, are you?

The size of that boiler you're installing has to do *only* with the amount of cold metal attached to it. That's all.

You see, the steam lives *inside* the pipes. It doesn't know about insulation, new windows, doors or weather-striping. Nor does it care. All the steam cares about is cold pipes and radiators. That's the enemy. That's the stuff that wants to turn the steam into water.

A steam system is not at all like a hot-water system. When you size a replacement boiler for a hot-water system, you base the size on a current heat-loss calculation. That's because in a hot-water system, you're circulating a liquid. You use that liquid to carry the heat from the boiler to the radiators. That liquid is the transportation system for the heat. And you can depend on that transportation system always being liquid. It's not going to change into something else at the last minute and ruin your day. Hopefully.

But steam is different. Steam is a gas. Oh sure, it's still the transportation system for the heat, but it has this additional quality: It can turn from a gas into a liquid!

That's part of what makes steam heating an art. It's also part of what makes boiler replacement difficult. You have to think a lot harder when you work with steam. You have to keep reminding yourself that this stuff is a

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The replacement boiler's responsibility (and yours) is simply to produce enough gas to fill the pipes and radiators before it can turn back into a liquid.

It's a race. It really is. It's the hot boiler verses the cold pipes and radiators. The goal is to send enough steam out into the system so you can make it to the finish line (that would be the furthest radiator) with just under 1-psig steam left. If the steam turns into water before it reaches that last radiator, well, then you lose the race.

It's a regular battle out there!

I always like to think of those old World War I movies when I'm sizing a replacement steam boiler. Remember *"All Quiet on the Western Front?"*

Picture all those doughboys ducked down in a muddy trench. Over there, across No-Man's Land, is a machine gunner. He's hunkered down in a concrete pillbox.

The sergeant shouts, *"Go get 'em, lads!"* and out of that muddy trench crawl the doughboys.

Now imagine that the trench is the boiler, the doughboys are the steam, and the machine gunner is the cold pipes. The doughboys are doing their best to cross No-Man's Land, but that darn machine gunner is busy mowing them down.

It's just like a heating system! The steam rushes out of the boiler and enters the No-Man's Land of the piping system. But those cold pipes just mow the steam down by turning it into water.

So the trick in replacement-boiler sizing is to make sure you have more "doughboys" than the enemy has "bullets."

Got it? Okay, back to the real world.

You *have* to base the replacement boiler's size on the connected radiation and piping. You have to because the radiation and piping is there. It's real and it wants to kill the steam.

As I said, the guy who sized the radiation back in the old days had to worry about the building's heat loss. But you're not going to change his pipes or his radiators, are you? No, you're not. So they're a constant; they're like a gigantic metal balloon, and it's up to you to fill that "metal balloon" with steam. But before you can do that, you have to know how big the "balloon" is.

So let's talk a bit about the old-timer who sized those radiators way back when. How come he made them so big?

How *"The National Poison"* Affects Replacement Boiler Size

That old-timer's been dead for years, but when he was alive he had to deal with some pretty peculiar people.

Back then, most folks liked to sleep with their windows wide open. You see, they were afraid of disease and they thought the cold night air was good for them.

There was good reason for their beliefs. All the "experts" at the time were talking about it.

In 1850, A.J. Downing, a well-known architect, wrote in his *Journal of Rural Art and Rural Trade* of the dangers of unventilated apartments and cooking stoves. He called this bad air *"the national poison."*

In 1866, Lewis Leeds, a heating and ventilating expert, told an audience at the Franklin Institute in Philadelphia he was *"forced to the conclusion that about forty percent of all deaths that are constantly occurring are due to the influence of foul air."* He then showed slides of people sitting in clouds of purple, *"vitiated"* air caused by the placement of the radiators and the closed windows.

In 1868, Catharine Beecher and her famous sister, Harriet Beecher Stowe, wrote about how *"tight sleeping rooms and close, air-tight stoves are now starving and poisoning more than one half of this nation."* The effects of rebreathing the air they just breathed out worried the sisters.

Folks also thought those new indoor toilets were passing sewer gas up into their bedrooms at night. Creeping death from the bowels of the earth coming to get you!

But seriously, when you think about all the people who died from mysterious diseases during the Civil War, it's easy to see how folks back then stopped and listened to these "experts." After all, this was the time when Louis Pasteur was first discovering the existence of germs. Before Pasteur, no one really knew what was going on.

So all this talk about the national poison led to an American fad during the early Twentieth Century: Folks slept with their windows wide open.

Ever watch those old silent movies? Remember how that guy with the handlebar moustache would put on one of those long nightshirts and a cap. Then, before he'd get under that cozy goose-down quilt, he'd open the window wide and take a few deep breaths?

People really did that. It was a national obsession. And because it was, the early heating engineers had to make some allowances when they sized steam radiators.

This is Edward Richmond Pierce writing in 1911:

"To the steam-fitter who is preparing to heat a house by steam or hot-water radiation, it is especially important to know whether the whole building, or certain rooms in the building, are to be closed off from heat supply during a portion of each day, or week, through the heating season.

"(Heating) engineers have decreed that an arbitrary addition to radiation shall be made, over and above other losses to be provided against, of 10 percent when the heating is continued during the day only and closed off during the night; ***30 percent when rooms are heated during the day and opened to outside air during the night;*** *and 50 percent when long periods of several days and nights prevail when the building is without heat."*

This helps explain why most of the radiators in older houses are so big. The early heating engineers based their heat-loss calculations on open windows! Most of the radiators they installed back then were 30% larger than they had to be—even on the coldest day of the year.

What Happened To All The Radiators?

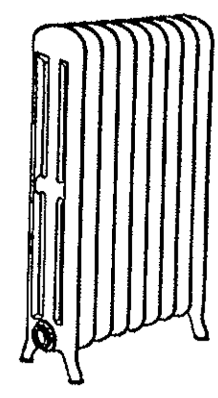
Nowadays, most folks don't sleep with the windows open. That's why their rooms get so uncomfortably warm. Many times, people living in these over-radiated homes will just close the supply valves to the radiators. Often, they'll remove several radiators from the house and store them in the garage or basement.

Think about that last steam job you were on. As you walked around the basement, how many capped riser take-offs did you notice? There used to be radiators attached to those pipes. They're not there anymore.

And this can have a big effect on the size of your replacement boiler. That's because the first step in sizing a replacement steam boiler is to measure all the radiation.

That, in itself, is easy to do. You just measure the radiator's height, count its sections and number of tubes. Then you can use these charts to come up with a total load in Square Feet of Equivalent Direct Radiation, or EDR for short. Each square foot EDR is equal to 240 Btuh when there's 70-degree air in the room and about 1 psig steam in the radiator.

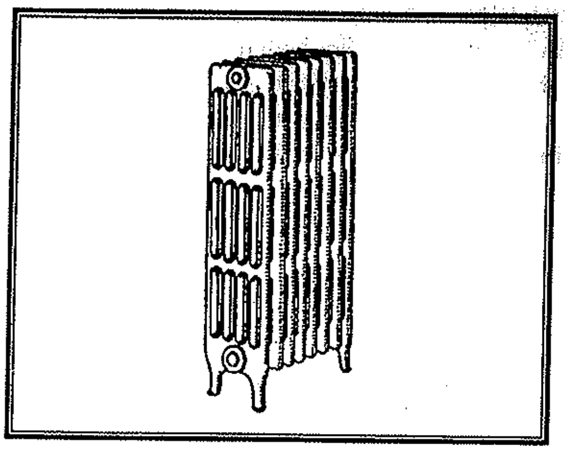
Standard Column Radiators



	Height (Inches)	Sq. Ft. Per Section
Single	20"	1.5
Column	23"	1.66

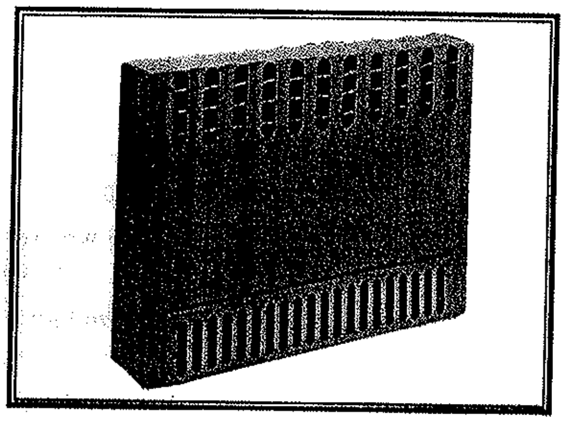
	26"	2
	32"	2.5
	38"	3
Two Column	20"	2
	23"	2.33
	26"	2.66
	32"	3.33
	38"	4
	45"	5
Three Column	18"	2.25
	22"	3
	26"	3.75
	32"	4.5
	38"	5
	45"	6
Four Column	18"	3
	22"	4
	26"	5
	32"	6.5
	38"	8
	45"	10

Thin-Tube (Water-Type) Radiators



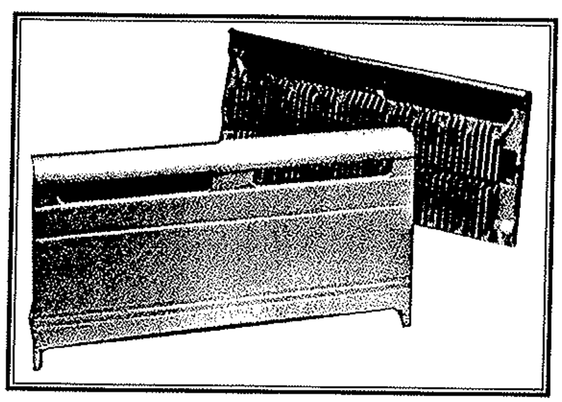
	Height (Inches)	Sq. Ft. Per Section
Three Tube	20"	1.75
	23"	2
	26"	2.11
	30"	3
	36"	3.5
Four Tube	20"	2.25
	23"	2.5
	26"	2.75
	32"	3.5
	37"	4.125
Five Tube	20"	2.66
	23"	3
	26"	3.5
	32"	4.33
	37"	5
Six Tube	20"	3
	23"	3.5
	26"	4
	32"	5
	37"	6
Seven Tube	13"	2.625
	16½"	3.5
	20"	4.25

Cast-Iron Radiant/Convectors



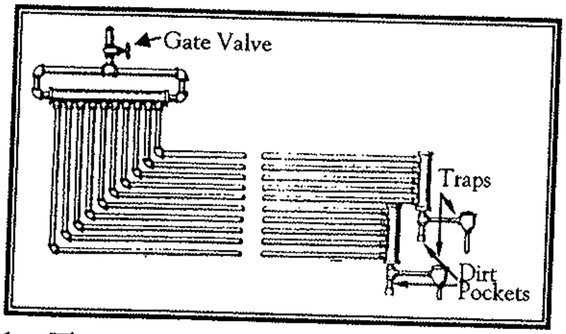
Width	Height	Sq. Ft. Per Section
5"	20"	2.25
7½"	20"	3.40

Cast-Iron Baseboard



Height	Width	Sq. Ft. Per Linear Foot
10"	2½"	3.4

Direct Pipe Coils



1. These ratings are based on the pipes being horizontal.
2. The ratings are in Sq. Ft. EDR *per linear foot of coil* (not total linear feet of all the pipe.)

Size Of Pipe	1"	1¼"	1½"
Single Row	.55	.675	.77
Two Row	1.05	1.30	1.45
Four Fow	1.83	2.27	2.57
Six Row	2.36	2.93	3.30
Eight Row	2.70	3.32	3.78
Ten Row	3.05	3.78	4.25
Twelve Row	3.38	4.19	4.73

If the radiators you're dealing with are different from the ones I just listed, you'll have to do a bit more research. One of the best books you can get for figuring radiation (and old boiler sizes) is the Hydronic Rating Handbook by T.R. Byrley. It's available from Color Art, Inc. 10300 Watson Road, St. Louis, Missouri 63127. Another excellent source for old boiler sizes is the Beacon Boiler Reference Book. Unfortunately, "Beacon" has been out of print since the early 1970s, but take a look on a heating wholesaler's book shelf and you'll probably spot a copy.

Normally, once you're through measuring the radiators, you'd take your total EDR rating to a boiler manufacturer's selection chart and look in the "Net Rating" column. Then you'd select the boiler that meets or exceeds your total EDR rating.

You'll notice when you're working with these charts there's also a column marked, "Gross Rating." The gross rating represents the total heat output available to the pipes and the radiators. It doesn't represent the total input from the flame, however, because you'll always lose some heat up the stack and through the boiler jacket. The "Gross" output is what we actually have available for the building.

A steam boiler's "Gross" output (or what they today call D.O.E. Heating Capacity) is about 33⅓% greater than its "Net" output. The difference between "Gross" and "Net" is the heat it takes to bring the system piping up to steam temperature. "Net" is the heat available to the radiators—after the steam has heated the pipes.

We call this extra 33⅓% capacity the "pick-up" factor. Years ago, boiler manufacturers used to allow as much as 60% "pick-up" capacity for the pipes. If you looked in a heating book from, say, 1900, you'd see the "Gross Rating" was more than half again as much as the "Net Rating." But as time went by, manufacturers realized 60-percent was a bit much, so, over time, this percentage came down. For instance, in 1940, the pick-up factor for a small steam boilers was still 1.56, but by 1958, they reduced it to 1.33.

I believe this downward trend over the years also had a lot to do with the type of systems we were installing. In 1900, we installed vapor systems. Vapor systems have very large pipes to accommodate very low steam pressure. Large pipes mean more "pick-up." By the 1950s, steam heating was more or less confined to larger apartment buildings and mechanically induced vacuum systems. Those systems use small pipes. Small pipes mean less "pick-up."

It always makes me stop and think about that built-in 1.33 "pick-up" factor when I'm sizing a replacement boiler for an old Turn-of-the-Century vapor system. I really don't think it's enough in most cases.

Here's another problem we have to deal with nowadays. The pick-up factor is based on the pipes that would normally connect a boiler to a certain amount of radiation. So, for instance, if the house has to supply 900 square feet of radiation, we would expect a certain amount of pipe between those radiators and the boiler, right? That's because the heating engineer based his system pipe sizing on the connected radiation.

But suppose the original engineer sized for open windows? I'll bet the folks who lived in that house removed many of those original radiators as the years went by. What happens if they did?

For instance, let's say you're going from room to room in an old house. You notice there are capped pipes where radiators once stood, but those radiators aren't there anymore so you put them out of your mind. After all, you can't measure what's not there, can you?

So you carefully measure what *is* there, convert its size to EDR (or Btuh) and write everything down. Then you take your total and sit down with your boiler catalog.

Let's say that total is six-hundred square feet EDR. Based on that, you select a replacement boiler from the "Net" column of your boiler book. That selection automatically includes the current 1.33 pick-up factor.

But wait just a minute. The engineer originally sized that job for 900 square feet EDR, not 600 square feet. Sure, someone removed radiators. *But the pipes are still there.*

Suddenly, your replacement boiler may not have enough capacity to heat all that piping *and* the radiators. It just may be too small to get the job done. The steam just might die in the pipes before it gets to the last radiators. You'll "lose the race" somewhere along that now-oversized piping network. You've got problems, and raising the pressure isn't going to help you. (But you know that now.)

This is why reputable boiler manufacturers usually include a footnote in their ratings tables. Weil-McLain, for instance states, "*An additional allowance should be made for unusual piping and pick-up loads—consult Applications Engineering Department.*"

Burnham's book has this advice: "*I=B=R net ratings shown are based on piping and pick-up allowances which vary from 1.333 to 1.315 for steam. Consult manufacturer for installations having unusual piping and pick-up requirements, such as intermittent system operation, extensive piping systems, etc.*"

"*Intermittent system operation*" can be something as simple as a new clock thermostat to go along with that new boiler.

In their spec sheets, Slant/Fin cautions, "*The net I=B=R output rating shown are based on an allowance for piping and pick-up of 1.33 for steam. The manufacturer should be consulted before selecting a boiler for unusual piping and pick-up requirements such as intermittent system operation, extensive piping, etc.*"

Watch out for those "et ceteras," they'll get you every time!

Read the footnote in H.B. Smith's catalog; you'll find the same warning: "*Consult the manufacturer before selecting a boiler for installations having unusual piping or pick-up requirements.... etc.*"

I'm not trying to beat this point to death. I just want you to appreciate the fine print in the catalogs. Don't say they didn't warn you. It's right there in black and white.

And as long as we're talking about potential problems, let's throw another variable into the pot: Insulation. Suppose asbestos once covered the pipes. Your job is to replace the boiler; you don't deal with asbestos. So the home owner has it removed.

But is he going to reinsulate those pipes once the asbestos is gone? Or is he just going to leave them uncovered, figuring those hot pipes will warm the basement? Have you thought about this? If not, then please stop for a minute and remember you're working with a gas—a gas that *really* wants to turn back into a liquid.

Remember, too, that when you remove any type of pipe covering and don't replace it, the pipes become radiators. They quickly turn steam into water because they're in full contact with the relatively cold air in the room.

Did you know the heat loss from uninsulated steam piping is more than five times as great as from insulated piping? Think about that big fresh-air inlet in the boiler room. How much cold air is hitting those boiler room pipes on a cold day? If steam condenses in uninsulated pipes, it's not available to the radiators. You have to allow for this in your boiler sizing.

A Safer Approach To Replacement Boiler Sizing

When you have a building where someone has removed radiation or insulation, but left the pipes as they always were, consider using a larger pick-up factor. In other words, instead of using the 1.33 pick-up factor that's built into the "Net" rating, try using 1.5. It's easy to do:

1. Just add up the radiation square footage as you normally would.
2. Multiply that by 1.5.
3. Convert this to MBH (thousands of Btus per hour) by multiplying by 240.
4. Then, select the boiler from the D.O.E. Heating Capacity rating column in MBH (this is the old "Gross" rating).

By using the "Gross" column instead of the "Net" column, you're taking out the manufacturer's built-in 1.33 factor and inserting your own 1.5 factor.

I've always had good luck with this technique on older buildings. I'll usually wind up with a boiler that's one section larger than the one I'd get by using the standard pick-up factor, but believe me, that extra section makes a big difference in the way the replacement boiler performs in that old system.

Using this method doesn't oversize the boiler to any great degree, it actually gets it very close to the true load.

I once watched an old-timer count the radiators that some home owner had disconnected. They now lay in storage out in the garage, but he counted them anyway. He figured the guy who owned the house just might have those radiators reinstalled someday - so he counted them when he sized his replacement boiler. He was figuring human nature into his sizing. Besides, he knew the installed piping could support those disconnected radiators.

He did all this, and then he selected the boiler from the "Net" column. In other words, he used the 1.33 factor, but he based it on connected *and* unconnected load. Phantom radiators!

Essentially, he was doing the same thing I would have done by using the 1.5 pick-up factor and the D.O.E. Heating Capacity (Gross) column. The only difference between our methods was that he had those "missing" radiators to work with.

I usually don't get that lucky!

Another problem with modern boilers is that they contain much less water than the old clunkers they replace. This is the price we pay for high efficiency.

If the building is large, your replacement boiler might need a boiler feed pump in order to keep up with the time it takes for steam to make it around the old piping system and return as condensate.

We'll talk more about this in Chapter 11 when we deal with condensate and boiler-feed pumps.

Once You've Replaced It, Don't Under- Or Over-Fire It

After you've sized that replacement boiler, it's time to start thinking about how big your fire should be. Ideally, your firing rate should match your connected load ("Gross" rating). Over-firing or under-firing can cause big problems in a steam system - problems which seem to be coming from all over the place.

If your fire is too small, two things can happen. First, since you're making steam at a less-than-required volume, it will probably condense into water before it reaches the last radiator. The other danger you face with too small a fire is that you won't be able to make steam at all! What would you think of a guy who tried to boil water in a spaghetti pot by using a Bic lighter? Not too bright, eh? Well, a too-small fire can give you the same effect. You'll burn a lot of fuel and get nothing in return. You'll be on "simmer."

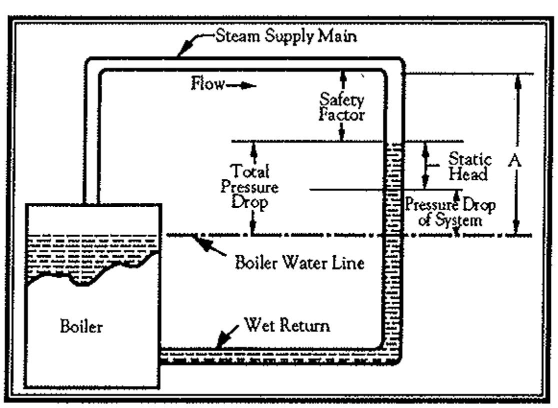
Now there is one fine point here I want to throw in. Under-firing might work if the folks in the building have a lot of radiators valved off. They're manually decreasing the load. You might set the fire on the day when everyone's warm, but the folks can change everything for you on a cold day when they start opening up those radiator valves. Get it?

This is also the reason why you can't under-size replacement boilers in buildings that are retrofitted with thermostatic radiator valves. On start-up, the valves are wide open. The same goes for the coldest day of the year: You have to prepare for the worst, so fire to the connected load, no less...and no more.

Which leads me to over-firing. This bad habit will give you as many problems as under-firing, but here, the problems will be a lot more subtle.

Here's what I mean. Some long-gone heating engineer selected the size of the pipes on that job of yours. But he's dead and the pipes ain't talking so we have to do a little thinking to figure out he had in mind.

We know from reading the old books that he sized the steam piping to carry a certain load (in pounds of steam per hour) at a pressure drop of one or two ounces per hundred feet. He figured out the pressure he'd have left at the end of the system after the steam lost whatever it was going to lose to pressure drop. Then he compensated for that pressure-drop loss with the vertical pipe "Dimension A." Remember this?



"Dimension A" is the difference in height between the center of the gauge glass and the bottom of the lowest horizontal pipe above the boiler water line. In a one-pipe, gravity-return steam system, "Dimension A" has to be a minimum of 28 inches.

That heating engineer understood steam. He understood this very important fine point most guys nowadays miss: *The system pressure drop, that is, the pressure you'll have "left over" at the end, is a function of the load, not the boiler pressure.*

In other words, we size steam pipes to carry a certain load (in pounds per hour). The heat loss of the building (and, subsequently, the connected radiation) determines that load. *But the boiler pressure (the cutoff setting of the pressuretrol) has very little to do with system pressure drop.*

You have to use your imagination for this. If you're a heating engineer and you want to move, say, 400 square feet EDR steam from the boiler to the radiators in a one-pipe system, you'll pick a pipe that will carry that load with a friction loss of one ounce of pressure per 100 feet of piping.

Now, the amount of space that much steam will occupy is based on very low pressure (typically two psig). At two-psig, a pound of steam occupies 24 cubic feet. So what we're done by selecting the pipe is put "five pounds in a five-pound bag."

But if we over-fire the boiler, we'll be putting more steam into the pipes than the engineer intended for them to carry. In other words, we'll be trying to get "ten pounds in a five-pound bag."

See? The piping is your constant. If you change the load by over-firing, you'll affect the steam's velocity. And that, in turn, will affect the system's pressure drop—and the "A" Dimension. The water may back up into the main.

Here's an example of how over-firing can affect the "A" Dimension. Suppose you added 45-percent to a properly sized, house-heating boiler (above and beyond the load, plus the pick-up factor). For instance, you replace a four-section, cast-iron boiler with a six-section, cast-iron boiler. Why would you do that? Who knows? Maybe you're looking for more water volume in the replacement boiler.

Fire that over-sized replacement boiler to its rated load and watch what happens. The steam velocity in the pipes will increase by about 45-percent. But the system pressure drop will increase by 211-percent!

In a small house designed for a two-ounce system pressure drop, the over-firing would add about four inches of water to the "A" Dimension. Do you have room for it? Probably. Most installers allow 28-inches for house-heating "A" Dimensions, even though the system will probably work with an 18-inch "A" Dimension. My guess is you won't even notice the extra water. Unless you have your replacement boiler up on blocks, that is.

But if you made the same over-firing mistake in a larger system, say, one designed for an eight-ounce pressure drop, that increase can make the water in the "A" Dimension stack nearly 16-inches higher than normal!

Will you have room for it? I doubt it. You only have 28-inches to work with. Once you add that extra 16-inches, the water will spill over into the main, shut off the air vent, rush up the nearest riser and hammer like crazy.

That's the danger of over-firing on most jobs. Because the system piping is a constant, you can't arbitrarily change the load.

The system-pressure-drop limit for the standard 28-inch "A" Dimension on a gravity-return system is eight ounces (which is equal to 14 inches of water column). That's for the entire system. That's why the design engineer sized the pipes for such a low pressure drop. Don't exceed it by over-firing.

Raising the boiler pressure also affects the system pressure drop, but only in a minor way. When you raise the boiler pressure, you compress the steam. A pound of steam at 7-psig, for instance, occupies only 19 cubic feet instead of the 24 it occupied at 2-psig. It contains essentially the same heat, it just takes up less space.

But by raising the high-limit pressure, you increase the density of the steam and that *will* increase the pressure drop across the system, but only by about 27-percent.

In the small house designed for a two-ounce pressure drop, the water level would rise about one inch higher in the "A" Dimension. You probably wouldn't notice it.

In a larger system, one designed for an eight-ounce pressure drop, that increase in pressure drop will stack the water about 3-3/4 inches higher in the "A" Dimension. Chances are, the "A" Dimension's safety factor will take care of this added height. Again, you probably won't notice the change.

Can you see the difference between load and pressure? Over-firing increases the load on the pipes. Raising the Pressuretrol cutoff setting doesn't. It just delivers the same load in a tighter package.

In the interest of safety and economy, the old-timers selected the piping to carry the right amount of steam at a very-low high-limit pressure. This is the reason most steam-heating systems work best when you fire *only* to the connected load and crank the Pressuretrol down. In most cases, raising the pressure does nothing except increase the fuel bills.

And over-firing does nothing except give you problems.

Understanding D.O.E. Ratings and AFUE

Let me run you through these new ratings we all have to deal with nowadays. You might not understand what they mean or how the rating agencies arrive at them.

First, nowadays all residential boilers are tested by their manufacturers according to the Department of Energy's (D.O.E.) test procedure. The Hydronics Institute, once known as I=B=R (the Institute of Boiler and Radiation Manufacturers) verifies the tests and confirms the manufacturer's testing.

The D.O.E. test procedure parallels the traditional I=B=R tests, but with a slightly different approach.

The old I=B=R test standards used by The

Hydronics Institute measured the Btu input and the Btu output, and established the official "Gross" output. They did this while maintaining the proper level of carbon-dioxide and stack conditions to assure steady-state efficiency. Their rating accounted for all operating losses, including those through the boiler jacket.

The D.O.E. test is a bit different. They measure the Btu input and the steady-state efficiency. Then they multiply the Btu input by the percentage of efficiency. That gives them the new official "Gross" rating category which they call "Heating Capacity."

Under this new D.O.E. procedure, we don't count the heat passing through the jacket as a loss because it's assumed to be of value inside the house. But for a given boiler, there's very little difference between the old "Gross" output (I=B=R test) and D.O.E's new "Heating Capacity."

Keep this in mind if you use the boiler replacement method I described above. It would be: Connected Radiation+50% and then a selection from the "Gross" rating column, or the "Heating Capacity" column.

Manufacturers also now test their boilers to determine their Annual Fuel Utilization Efficiency (AFUE). They base AFUE on tests which run through on and off cycles. These tests take off-cycle losses into consideration.

Simply put, AFUE measures a boiler's ability to extract heat from oil or gas over a full heating season. The AFUE increases as the burner's on-time increases until it reaches a steady-state efficiency.

"Steady-state" is the efficiency of the boiler when the burner is running. Any time the burner cycles on and off, the AFUE drops because of off-cycle losses. The AFUE drops most sharply when the burner operates between 10% and 30% of the time.

The longer the burner is on, the higher the AFUE will be. Don't get too hung up on this with steam, though, because we can have great AFUE and no heat in the building. The burner runs all the time, sure, but the folks upstairs are freezing.

Think in terms of *system* efficiency—how well the *system* delivers heat to the people. There's more to steam heating than combustion efficiency and stand-by losses.

Read on.