A Discussion of Boiler Design

An Analysis of the Advantages and Disadvantages of the Wet Section Design in Four Types of Boilers

- Laars Series H
- Horizontal Water Tube (HWT)
- Cast Iron Sectional (CIS)
- Horizontal Fire Tube (HFT)

LAARS Heating Systems Company
A subsidiary of BRADFORD WHITE Corporation

I. Introduction

For many years, in fact until the introduction of the Laars Heating Systems boiler, three types of boilers dominated the American market. They were the Cast Iron Sectional (C.I.S.), the Horizontal Water Tube (H.W.T.), and the Horizontal Fire Tube (H.F.T.). Hundreds of thousands of these boilers are in use and, it must be said, that *when all conditions under which they operate are satisfactory*, they provide acceptable efficiency, reliability and service life.

Over a period of 50 years these three designs had gradually displaced the vertical fire tube boiler which at one time had been the accepted standard of design. The vertical fire tube boiler had, in its day, displaced the earliest boilers which were fashioned after the tea kettle, with steam being drawn out of the spout (Fig.1).

Unfortunately, the conditions under which boilers operate are not always ideal or even satisfactory. This is attested to by the existence of a large and thriving boiler repair business. The *Yellow Pages* in any large American city give some idea of the size of the boiler repair business. These listings do not take into account repair work done by small firms who do not list in the *Yellow Pages*, or by plumbers or by boiler manufacturers and their representatives.

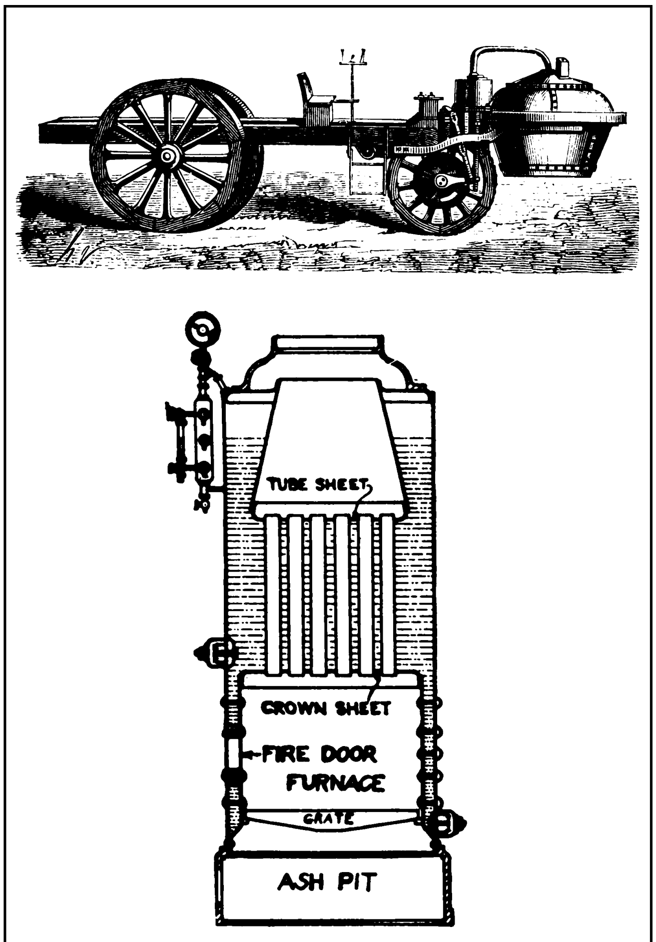


Figure 1. Top: early "Tea Kettle" boiler. Bottom: typical vertical fire tube boiler.

Since all of these companies derive their income from the fact that boilers fail, it is evident that in the current *state of the art* boilers are something less than 100 percent reliable and foolproof.

It must be emphasized that, while some boilers are of poor design and/or are manufactured in a careless and shoddy way, most boilers are of good quality and the failures which sustain the thriving boiler repair business are due, for the most part, to the unfavorable conditions under which the problem boilers have been operated.

It is precisely because boilers are so frequently called upon to operate under unsatisfactory field conditions that a major goal in the Laars design was to develop a boiler that will *live happily* under field conditions which conventional boilers cannot tolerate.

Among military and commercial aircraft designers the term *forgiveness* has a special meaning. A *forgiving* airplane is one which accepts and survives pilot error, unexpected wind and weather changes, or mechanical failure.

In this bulletin we will attempt to explain in detail how *forgiveness* has been designed into the Laars boiler design.

First, let us list some of the field problems which lead to boiler failures.

1. Introduction of raw water into the heating system.
2. Rapid changes in boiler water temperature.
3. Operating the boiler with low water temperatures.

II. The Problem of the Open "Closed System"

This is usually caused by (a) one or more leaks in the system or (b) the water-logging of the expansion tank which results in the expulsion of expanded water through the pressure relief valve every time the system temperature rises.

In a completely tight, sealed system the amount of sludge or scale found is quite small, and most boilers will tolerate years of accumulation without difficulty. However, if raw water, *even in small quantities*, flows in the system we have an entirely different situation. The nature of the difficulties created by the inflow of raw water depends on the quality of the raw water.

If the raw water is soft and/or high in oxygen, or of high conductivity, or has a low pH, it will attack the metallic surfaces of the boiler, piping and radiation. This corrosion process sloughs off solid material which is carried through the system by the water stream. Since suspended solids always drop out at the point of lowest velocity, it is obvious that a boiler design in which the water moves slowly will tend to accumulate sludge more rapidly than one in which the water moves at high speed.

Let's examine the water velocity through the various boiler designs, as shown in Table 1.

From this table it is clear that the water moves more slowly in the Cast Iron Sectional, the Horizontal Water Tube and the Horizontal Fire Tube boilers than in the Laars or even the system piping, and that suspended solids in the water will eventually settle in the *other three* boilers. In fact, in all three cases the water moving through the boiler is actually moving much more slowly than at any other part of the system. By contrast, the water moving through the Laars boiler is moving faster than through the system piping. This explains why sludge never deposits in the Laars boiler and why the Laars never needs blowing down.

Another important point to consider is what effect the sludge deposit has on the boiler. Fig. 2 shows a cutaway of all four designs. An examination of these drawings makes it obvious that in the case of the C.I.S. boiler, the sludge will settle in the lowest part of each section, which, unfortunately, is also the most intensely fired surface in the whole boiler. This is also true of the H.W.T. boiler where the sludge can only settle in the bottom of the header sections and in the lower-most row of tubes which, like the C.I.S., is the most intensely fired area. In both designs the accumulation of sludge at these critical points prevents the water from carrying heat away and the result is section-cracking and tube burning. In the case of the H.F.T. boiler sludge settles in the bottom of the drum which is unfired, and no harm results.

A moment's reflection leads one to the conclusion that the bottom surfaces of the Cast Iron Sectional and the Horizontal Water Tube boilers are the most damaging places in the whole heating system for sludge to accumulate.

The above paragraphs have to do with the effects of the inflow of soft or aggressive water into a heating system. If, however, the incoming water is hard, the effects are somewhat different.

The scale-forming minerals are precipitated out as the water is heated, and these minerals tend to accumulate on the hottest surfaces. The rate of mineral accumulation (scaling) is materially reduced where the water moves rapidly. In the case of the C.I.S., the H.W.T., and the H.F.T., because of the slow water movement, scale will accumulate on the hottest surfaces. This will result in the section cracking in the C.I.S. and burning out of the lowest tubes in the H.W.T., or burning out of the furnace tube in the H.F.T.

In the case of Laars boilers, the high water velocity again proves advantageous, for it drastically reduces the *rate* of scale accumulation. If the amount of scale-forming minerals entering the system is great because of large additions of water to the system, then scaling of the tubes, even in a Laars, is inevitable and the tubes will have to be cleaned out.

If any boiler is fired for long periods under scaling conditions serious damage will result. If this happens to a Laars boiler, the whole wet section can be readily removed *actually in minutes* and readily repaired. Compare this job with the time and cost of re-tubing a steel tube boiler, or replacing *sections* in a cast iron boiler.

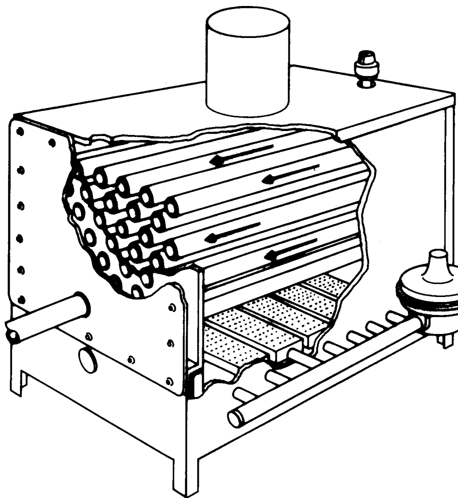
To sum up the *forgiveness* of Laars' to incoming raw water, if the incoming water is soft and corrosive the resultant sludge will be carried away from the boiler and diffused through the system. If the incoming water is hard the high velocity water flow through the tubes of Laars will reduce the rate of scale deposit or eliminate it altogether. Further, since all internal wet surfaces in Laars are either copper or porcelain enameled cast iron or bronze, the Laars boiler itself is immune to corrosion attack from raw water.

III. The Problem of Rapid Changes in Water Temperature

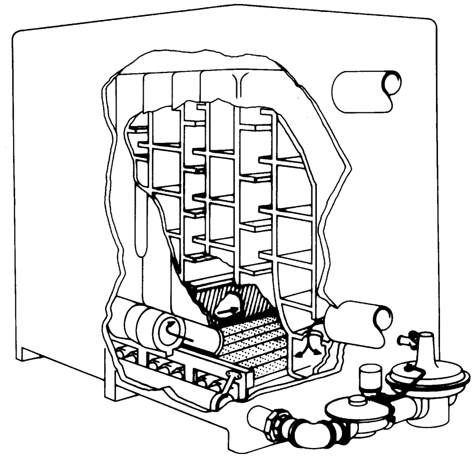
Rapid temperature changes sometimes occur in combined heating-cooling systems. Everyone agrees that a well designed system should have safeguards to prevent the introduction of chilled water into a boiler and to prevent the rapid cycling of a system between heating and cooling. The hard facts are, however, that many boilers are subjected to this form of punishment. This arises out of improper system design, improper installation and wiring, tampering with the control

	CAST IRON SECTIONAL	HORIZONTAL WATER TUBE	HORIZONTAL FIRE TUBE	LAARS HL	SYSTEM PIPING
VELOCITY	.0335 ft./sec.	.145 ft./sec.	.085 ft./sec.	7.0 ft./sec	4.0 ft./sec.
VOLUME (Water Content)	139 gal.	41 gal.	265 gal.	2.5 gal.	—

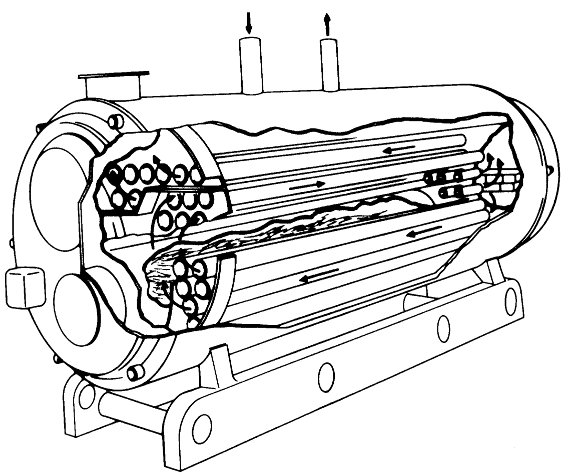
Table 1. Table of water velocities through various types of boilers, compared to normal flow in piping system. Figures are approximate for boilers of 1,000,000 BTU input.



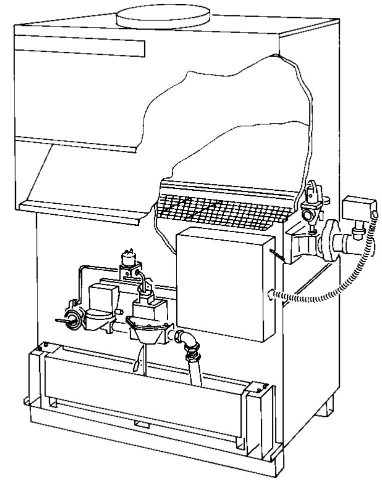
Horizontal Water
Tube Boiler



Cast Iron
Sectional Boiler



Horizontal Fire
Tube Boiler



Laars Heating Systems' Boiler

Figure 2. Cross-section drawings of typical boiler designs.

system after installation, etc. This situation is so common that the American Gas Association required that the following statement be made a part of the installation instructions of every gas fired boiler bearing the AGA Seal of Approval:

> *1.26.4 Boilers shall be accompanied by detailed printed instructions which shall state and illustrate that boilers, when used in connection with refrigeration systems, shall be installed so that the chilled medium is piped in parallel with the heating boiler with appropriate valves to prevent the chilled medium from entering the heating boiler.*
>
> *These instructions shall also state that when hot water heating boilers are connected to heating coils located in air handling units where they may be exposed to refrigerated air circulation, that such boiler piping system shall be equipped with flow control valves or other automatic means to prevent gravity circulation of the boiler water during the cooling cycle.*

The rapid chilling of conventional boilers is damaging in two ways. In the case of the Cast Iron Sectional, it creates tremendous mechanical stresses due to differential expansion between the upper portion of the wet section which remained chilled while the lower portion is being fired. This results in section cracking. In the case of water tube and fire tube boilers the expansion of the hot tubes is opposed by the chilled tubes, resulting in tube pulling and tube necking.

Operating the boiler with chilled water also creates condensate on the cold surfaces exposed to the flue products. This is particularly destructive to steel tubes. It is common to find steel tubes corroded through from the flue side in boilers operated in this manner.

While we object to the rapid chilling of a boiler as being poor practice, the Laars design has taken into account that this may happen. Differential contraction stresses have been eliminated by permitting the whole wet section to *float* in the boiler housing. The heat exchanger is free to expand and contract without restraint. Further, all tubes are of copper which is highly corrosion resistant and all tubes operate at the same temperature.

As a result of a forgiving design, no Laars has ever failed due to expansion or contraction stresses and no Laars has ever failed due to corrosive attack of condensate on the fireside of the copper tubes.

IV. What About Boiler Water Content?

During the design phase of the Laars boiler the matter of water content was given much thought. A careful analysis of all advantages and disadvantages of both large and small water content leads to the inescapable conclusion that the advantages were overwhelmingly in favor of a lower water content design.

Of the four boiler designs illustrated above, the Laars boiler contains the least amount of water (see Table 1).

We have already stressed the importance of high water velocity in a boiler. It is impractical to attempt to move a large body of water in a boiler at high velocity for two reasons. First the sheer quantity of water to be moved would require a fantastically large and expensive pump, and second, the cost to provide electric energy for such a large pump would be prohibitive.

By way of example, if one tried to move water through a 1,000,000 BTU horizontal water tube boiler at the same velocity commonly used in system piping (which is much slower than the velocity through the Laars boiler) the pump would be required to move 2350 g.p.m. and the motor size would be approximately 30 h.p. A pump of this size would have an inlet and outlet connection of 10" and would cost approximately $3,000. To achieve the same velocity, the C.I.S. and the H.F.T. boilers would require even larger and more costly pumps. In contrast to this, in the Laars design, the pump required to achieve this high velocity shown is no different than the pump normally used on any low velocity boiler of the same size.

Consideration of safety also makes a low water content very desirable.

Statistically, while modern boilers have an excellent safety record, the fact remains that boilers do, from time to time, run away and explode. It is true that this can only happen when at least two or three safety devices fail at the same time. When this happens the amount of destruction that takes place is in *direct proportion* to the amount of water in the boiler at the time of explosion. Catastrophic explosions caused by 20 and 30 gallon water heaters with very low heat inputs show that *the real danger lies in the energy stored in the water,* not the heat-input, *per se*.

Table 2 compares the destructive energy stored in the three types of boiler designs. The question may fairly be asked: *"Which of the above boilers should be in a school, a hospital, a hotel, or anywhere where people are?"*

The Laars boiler is explosion proof. First of all the water content is very low (see Table 1). In addition the copper tubes themselves act like *fusible links* in a runaway condition. Before the steam temperature can build to a dangerous level, the copper tubes will fuse and safely release any built-up pressure. The damage to the boiler would be limited and the boiler can easily be repaired and quickly returned to service.

A large water content in a boiler makes it respond sluggishly to system demands. The characteristically long warm up time required by such a boiler has resulted in the practice of keeping these boilers hot for long periods awaiting a system demand. The cost in fuel to offset the heat losses during such standby periods can be very great indeed.

The only advantage one might claim for a large water content is the fact that, because the rate of temperature rise in such a boiler is slow, boiler water temperatures can be more easily controlled. This was an advantage many years ago when operating thermostats were much slower acting and less responsive than they are now. However, modern thermostatic controls with their quick response characteristics make it possible to design a modern, low water content boiler with its obvious advantages of greater safety , quick response, self-cleaning capability, and higher heat transfer capabilities without giving up anything in the way of smooth operation.

V. The Subject of Heat Transfer in a Boiler

In the process of transferring heat from the hot gas to the water in a boiler, two major barriers are encountered. They are (a) the gas film on the fireside, and (b) the liquid film on the wet side (see Fig. 3).

On the wet side water tends to form a stagnant

	CAST IRON SECTIONAL	HORIZONTAL WATER TUBE	HORIZONTAL FIRE TUBE
VOLUME (Water Content)	139 gal.	41 gal.	265 gal.
BTU IN WATER a) 500 psi to 70° F atmos.	475,000	143,000	930,000
EQUIV. 60%* DYNAMITE LBS.	32	10	63

*Thermal/mechanical energy conversion = 10%.

Table 2. Comparison of destructive energy stored in three types of boilers. Figures are based on boilers of 2,000,000 BTU input (assuming explosive rupture at 500 psi).

liquid film which clings to the metal surface. This acts as an insulator and greatly impedes the flow of heat from the metal to the water. If the water is forced to move at high velocity this stagnant film will be scoured away and the flow of heat to the water will be greatly speeded up.

Table 3 shows that the rate of heat transfer in a boiler with *forced convection* (such as a Laars) can be as much as 10 times greater than a boiler with *free convection* (such as a Cast Iron Sectional, a Horizontal Water Tube or a Horizontal Fire Tube). To put it simply —because of the high speed water flow through the Laars each square foot of surface in a Laars will pick up from 4 to 10 times as much heat as a square foot of surface in a boiler designed for *free convection*.

VI. Why Finned Tubes?

On the hot gas side a similar condition prevails. The hot combustion gases which contact the transfer surfaces cool down and cling in a thick film to the metal. Again (as with the water) this stagnant film acts as an insulator and blocks the flow of heat. A further problem on the gas side arises because of the low heat content of the gas as compared to the water on the other side. A cubic foot of water when raised 10° will absorb 624 BTU, whereas one cubic foot of air when raised 10°F, will absorb only .165 BTU. To put it another way, for every cubic foot of water brought into contact with the transfer surface (and increased in temperature by 10°F) one has to supply 25 cubic feet of combustion products (at 2,000°F). Further, because of the poor conductivity, the gas gives its heat up more slowly than the water can absorb it.

It is for these reasons that when heat is being transferred from a liquid to a gas or vice versa, it is always desirable to present much more surface to the gas side than to the liquid side. This has given rise to the almost universal use of finned surfaces on the dry side in almost every place where heat is flowing from gas to liquid or liquid to gas.

Cast iron radiation has given way to finned baseboard radiation. In refrigeration, pipe coils have been displaced by finned convectors. In fact, in the heating and cooling field *the only place where finned surfaces are NOT universally used is in boilers.*

Almost all finned tubing is comprised of two pieces, a separate fin and a tube which are joined by soldering, brazing or pressing. The connection between the fin and the tube is extremely critical because all the heat collected by the fins must flow through this joint to the tube wall and from there to the water.

These methods of joining are quite suitable for general heating and cooling applications. However, soldered, brazed or pressed fin joints are not suitable for use in a boiler firebox because the high

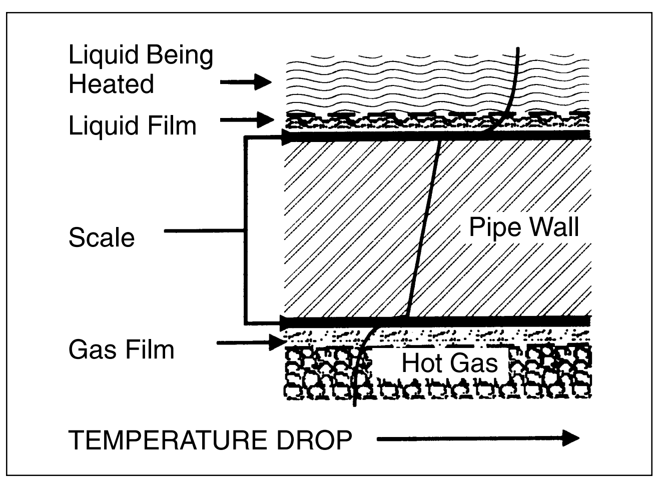


Figure 3. Illustration of heat transfer from a hot gas through a pipe wall to a liquid (such as water).

temperatures found there can destroy the critical heat conductive connection between fin and tube.

For this reason the use of extended surface material in boilers was delayed until the development of the integral fin copper tube. The development of the integral fin copper tube gave to the boiler designer an ideal heat transfer material which enabled him to make many basic improvements in boiler design.

It offers an almost ideal ratio of 8 times more surface to the gas side than to the wet side. It is made of copper, which is 8.5 times more conductive than cast iron or steel, and it is highly corrosion resistant to both water and flue gas products.

It has enabled the boiler designer to provide all the heat transfer surface necessary for efficient operation and, at the same time, reduce the water content and increase water velocity to optimum levels.

Another very important point is that it is now possible for the first time to arrange the heat transfer surfaces in such a way that every linear inch of tube is working at a maximum efficiency and absorbing exactly the same amount of heat.

In the past, one of the serious limitations of boiler design was the fact that with conventional material (cast iron, steel tubes or plain copper tubes) the size and bulk of the transfer surfaces made it impossible to place more than a small percentage of the surface in direct contact with the flame and in position to absorb the radiant energy of the flame mass.

Boiler designers have long recognized that only those surfaces which come in contact with uncooled combustion products and which are exposed to the radiant energy of the flame mass are working efficiently. The sheer bulk of conventional transfer materials made it impossible to place more than a fraction of the surface in this efficient position.

Let us examine this important point in detail:

Take for example a 1,000,000 BTU horizontal steel water tube boiler of current design. The drawing in Figure 4 shows the tube and firebox arrangement.

At the tube row (1) the flue gases are 2,000°F and the tubes in Row (1) are exposed to the full radiant energy of the 1 flame mass. The tubes in Row (7) are surrounded by gases which have been cooled by the

FLUID GIVING UP HEAT	FLUID RECEIVING HEAT	STATE OF CONTROLLING RESISTANCE		TYPICAL FLUID	TYPICAL APPARATUS
		FREE CONVECTIONS U	FORCED CONVECTIONS U		
Liquid	Liquid	25 - 60	150 - 300	Water	Liquid Heat Exchangers, etc.
		5 - 10	20 - 50	Oil	
	Gas	1 - 3	2 - 10	Water to Air	Hot Water Radiators, Cooling Tower
	Boiling Liquid	20 - 60	50 - 150	Water	Brine Coolers
		5 - 20	25 - 60	Oil	
Gas	Liquid	1 - 3	2 - 10	Air to Water	Air Coolers, Economizers
	Gas	0.62 - 2	2 - 6	Gas to Steam	Steam Superheaters
	Boiling Liquid	1 - 3	2 - 10	Gas to Boiling Water	Steam Boilers
Condensing Vapor	Liquid	50 - 200	150 - 800	Steam to Water	Condensers, Feed Water Heaters
		10 - 30	20 - 60	Steam to Oil	
	Gas	1 - 2	2 - 10	Steam to Air	Steam Pipes in Air, Air Heaters
	Boiling Liquid	300 - 800		Steam to Water	Vacuum Evaporators
		50 - 150		Steam to Oil	

NOTE: Under special conditions higher or lower values may be realized.
SOURCE: W.H. Mc Adams, "Heat Transmission" (McGraw-Hill Book Co., Inc.)
from data given by A.P. Colburn (copyright 1942)

Table 3. Over-all coefficients "U" expressed in BTU per hour per square foot per degree F.

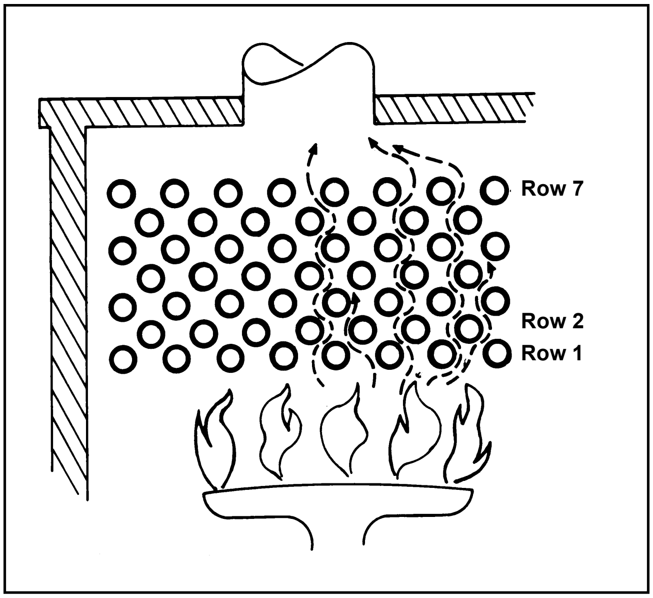


Figure 4. Section through horizontal fire tube boiler (1,000,000 BTU/hour input).

lower rows to only 500°F, and since they are shadowed by the lower rows they are not exposed to radiant energy.

A complete mathematical analysis, compares the amount of heat being absorbed by Row (1) as compared with Row (7) and discloses the amazing fact the *Row (1) absorbs approximately 10 times as much heat as Row (7).*

Without going into a similar analysis of heat transfer efficiency in the cast iron and fire tube boilers, a close look at the illustrations in Fig. 2 make it clear that all but the directly-fired surfaces in these boilers are operating at the same disadvantage as the upper rows of a horizontal water tube boiler.

In the case of the cast iron boiler, the bottoms of the sections are directly fired and operate under the same condition as the lower tubes in the example above. The upper part of the sections receive almost no radiant energy and are wiped by cooled flue products.

In the case of the horizontal fire tube boiler only the furnace tube, where the combustion takes place, receives the radiant energy of the flame mass and the benefit of the hottest combustions gases. The subsequent passes operate exactly the same as the upper rows of the horizontal water tube boiler.

Compare this with the Laars wet section (see Fig. 2). Note that there is only one row of tubes, that each and every tube is exposed to the same radiant energy of the flame mass and each and every tube is surrounded by flue gases of exactly the same temperature. Each tube is therefore working at maximum efficiency.

VII. The Fallacy of Rating by Horsepower

This is a good place to discuss the practice of rating boilers by square feet of surface per boiler horsepower.

By way of explanation, a boiler horsepower is equal to a heat output of 33,475 BTU per hour. Therefore, if a boiler is rated at five square feet per boiler horsepower, a clearer and more precise way of saying the same thing would be to say that the AVERAGE square foot of surface at the boiler is absorbing approximately 6,695 BTU per hour. The word AVERAGE must be stressed because from the above it is clear that in the typical Cast Iron Sectional, Horizontal Water Tube or Horizontal Fire Tube the lowest (hottest) surfaces are absorbing approximately 11,300 BTU per square foot, whereas the upper (coolest) surfaces are absorbing approximately 1,340 BTU per square foot. This should be compared with the surfaces in the Laars where there are no overloaded surfaces nor any idling surfaces, and where EACH square foot (not the average square foot) absorbed 10,500 BTU, no more—no less.

Not too many years ago, boiler manufacturers limited their efforts to the manufacture of the wet section only. Others were called in to construct the firebox (formerly called the furnace), provide the setting and lagging, supply the burners, design and install the controls and other trim, etc. In those days the buyer of a boiler was really buying square feet of heat transfer surface. The yardstick *square feet per boiler horsepower* was a crude but practical way of measuring what was being offered by the boiler (wet section) maker. Also in those days the common fuels were coal and oil, both of which tended to foul the transfer surfaces. This made it desirable to provide extra surface to offset the expected reduction in transfer effectiveness.

To begin with, a modern gas boiler simply doesn't foul the transfer surfaces. In fact, in order to obtain the AGA or CGA certification, combustion must be so clean and complete that no more than .04% of carbon monoxide may be tolerated in the flue products—under any test conditions.

The combustion products of a boiler which comply with these requirements are absolutely clean and leave no deposits whatsoever. It is obvious that, when some surfaces are operating at 1/10 the efficiency of others, the total amount of surface has very little meaning as a measure of boiler efficiency or quality. Obviously, how efficiently the surfaces are being utilized is far more important than the total surface.

Note the illustration in Fig. 5 shows how the finned tube is baffled in the Laars wet section to enhance the effectiveness of the fin tubes. Without the baffles, the upper 25% of the fin surface is not efficiently utilized.

Figure 5. Patented Laars Heating Systems baffle.

The baffle not only forces the flue gas to pass over the upper fin surface but it also speeds up the flow of hot gas across the fins and creates turbulence, which greatly increases the transfer efficiency. In the Laars, the flue gases are cooled to the practical minimum in a passage of less than two inches.

Actually, with this design it is a relatively simple matter to force more heat into the water and to reduce the flue gas temperature even lower. The practical needs of achieving good draft in the chimney and of preventing the flue gases from condensing and corroding the building vent system make further reductions in flue gas temperature undesirable.

VIII. Can Boilers be Too Efficient?

At first thought it might seem that the more surface a boiler has, the better it must be. A careful consideration of the facts brings us to the inevitable conclusion that this is not at all so. It is true that, all other things being equal, adding more heat transfer surface to a boiler will lower the flue temperature and therefore increase the efficiency. However, lowering the flue temperature too much can be detrimental and even dangerous.

This is an important point and worth a detailed explanation. To begin with, the flue gases must leave the boiler with enough heat to perform two vital tasks; there must be enough residual heat in the flue gases to (a) keep the column of gas in the vent and chimney hot enough to maintain good stack action, and (b) to offset the heat losses through the walls of the venting system.

If the flue gases do not contain enough heat to perform both vital tasks even in the coldest weather, the combustion products will spill back down into the boiler room. Unless the boiler room is extremely well ventilated (not a usual condition in cold weather) the combustion products will lower the oxygen content of the air entering the boiler, which in turn may result in poor combustion and the contamination of the room with carbon monoxide. The combustion of gas generates flue products which contain large quantities of moisture. For this reason the residual heat in the combustion products leaving the boiler must be great enough to keep all internal surfaces of the vent system above the dew point of the gases. If the internal surfaces of the vent system are allowed to drop below the dew point, moisture in the flue products will condense on cool surfaces. The condensate is quite acid, actually a weak solution of H_2CO_3 and H_2SO_3, and unless these surfaces are non-metallic or stainless steel, serious corrosion will result.

A look at the alignment chart (Table 4) will make clear the relationship between flue loss, flue temperature and combustion efficiency.

From the alignment chart it can be seen that if a boiler is operating in the usual range of 7% to 9% CO_2 and if the actual combustion efficiency is 80% the flue gases will be in the range of 305°F to 410°F (above ambient). To drop the flue gas temperature below these values is to approach the condensate point (dew point) of the flue gases and may cause serious problems in vent maintenance.

From the above it is clear that the boiler operating at 80% combustion efficiency is close to the uppermost limit of safe practice.

As with all design problems the best solution is achieved when all important factors are brought into a balanced relationship with each other. Just as a boiler can have a burner that is too large or too small, a vent or fire box that is too large or too small, it can also have too much or too little water or too much or too little surface. We believe that the Laars design has brought all of the elements of a boiler into balance and that the design as a whole represents a significant step forward in the art of boilermaking.

IX. System Sizing

All hot water boilers are tested to meet the requirement of the American Gas Association and the United States of America Standards Institute. The performance testing includes a requirement for 75% thermal efficiency heat introduced into the water as a minimum. In addition, the American Gas Association allows an additional 5% to the heat output of the boiler to cover radiant heat lost by the boiler into the building. Laars Heating Systems meets these requirements, as do all boilers designed to bear the seal of the American Gas Association.

The testing is conducted under standard conditions of barometer and temperature, etc. and not all boilers operate under these optimum conditions. For one thing, boilers located in a penthouse or an enclosure on top of a building can add no heat to that building by radiation from the boiler casing, even though a boiler bears an A.G.A. 80% efficiency rating. Under these conditions such a rating is not correct.

In sizing a boiler for a given system and heat load, it is important to introduce safety factors in the calculation to take care of situations as that of the boiler located in a rooftop enclosure, and to cover fuel supply problems. During an extremely cold period the whole gas distribution system is heavily taxed, and in some areas where mains are marginal the gas pressure will drop. If a boiler has been sized with no safety factor it can fail to produce its rated output at the very period when its maximum capacity is most needed.

A boiler is generally designed into building equipment to last in excess of 25 years. During this period of time new uses for the facility arise and many additions to the heat load can occur. Unless some safety factor has been computed into the initial demand the later loads will cause a serious problem.

Some boiler manufacturers counsel the use of the 80% efficiency factor without any reservations, but you will serve your customer better if you insure that he has a safety factor built into his boiler sizing.

Be sure to consider the altitude above sea level when sizing a boiler. All BTU ratings are for sea level; as you reach higher altitudes the density of the fuel is reduced and the amount of oxygen is likewise reduced. Normally boilers are derated 4% for every 1,000 ft. altitude above sea level and Laars will build the boiler to suit the altitude at which it is to be operated.

Be careful of gas specifications. Occasionally the BTU content of a fuel is different than the standard which is used by the American Gas Association in rating appliances.

X. Corrosion in Hot Water Heating Systems

The electrochemical theory of corrosion proposes that corrosion is accomplished by a network of short-circuited electrolytic cells. Metal ions go into solution at the anodes in amount equivalent to the reaction of the cathodes. In case of iron and a more noble metal (copper), the cathodic reaction is proportional to the concentration of dissolved oxygen in the aqueous environment.

In closed hot water heating systems the water quality is either soft or medium hard, and free oxygen is soon exhausted. Further corrosion of the system cannot occur.

Cast iron is resistant to corrosion even in the presence of oxygen (where fresh water is added to a closed system). The graphite phase mixes with iron oxides, forming a compact layer over the unattached iron. The graphite-oxide layer is *self-limiting* in stopping the galvanic action between cast iron and the more noble metals, brass and copper, because of its high electrical resistance. This is evidenced by the customary use of brass impellers in cast iron pump housings. More emphatic proof of this phenomena is the fact that all city water mains throughout the country are made of cast iron and have literally tens of millions of brass and copper service connections to them. These mains are laid in every kind of acidic and corrosive soils and carry raw water with entrained oxygen. Many of these water mains have been in service for nearly a century without serious corrosion damages whether from within or on the outside.

Laars Heating Systems has been using copper tubes rolled into grey iron headers for more than forty years in hot water systems heating both raw water and closed systems, without any evidence of difficulties related to corrosions on the dissimilar metals. Laars' cast iron headers have yet to be damaged by electrolytic corrosion. Some closed hot water heating systems using dissimilar metals are still in operating in many areas of this country after 70 years of satisfactory service.

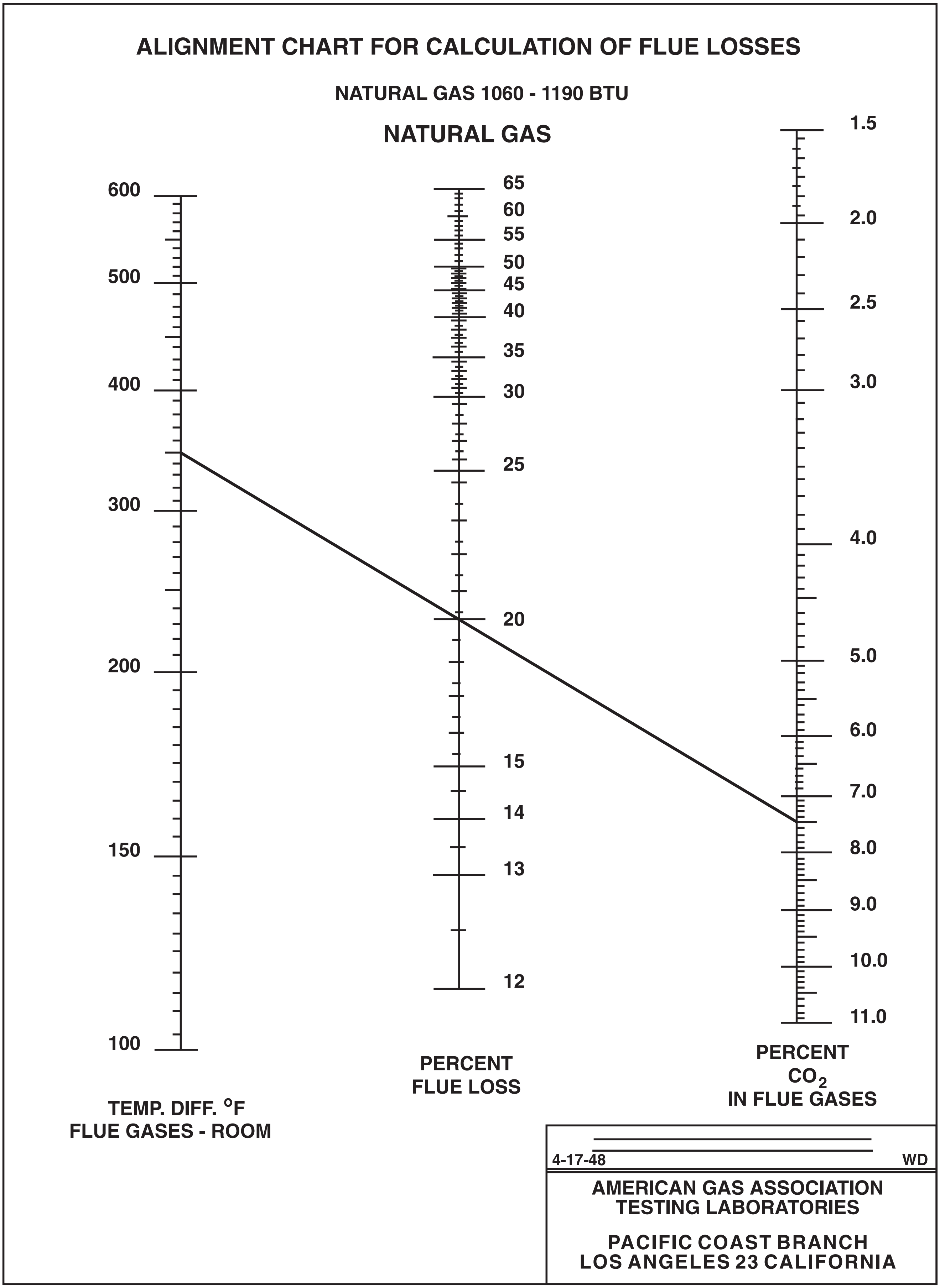


Table 4. Flue alignment chart.

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