# DESIGN FLEXIBILITY IN A STOKER FIRED SHOP ASSEMBLED MODULAR BOILER

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## INTRODUCTION

During the past years, American industry has felt the pressure of a highly competitive market in conjunction with increasing manufacturing, construction, and fuel costs. In most industrial applications, a source of saturated and/or superheated steam is a must. An efficient, economical steam generator will provide the required quantity of steam to be utilized in most conventional industrial processes.

It is the intent of this paper to introduce the shop assembled modular boiler as an economical approach for industrial steam generation. Design criteria, fuel versatility, and flexibility of arrangements will be discussed in detail, and modern engineering technology will be emphasized. A complete analysis of different designs of furnaces, superheaters, and boiler banks necessary to meet customer specifications and fuel requirements will be made. Typical solid fuels will be compared, and their influence on the selection of different boiler components will be addressed. The fuels to be considered are bituminous and sub-bituminous coals, lignite, wood, and bagasse. This discussion will describe boilers up to 150,000 lbs/hr of steam generated with superheater outlet temperatures and pressures up to 900°F and 1600 psig respectively, firing fuels with low to severe fouling and slagging characteristics.

## GENERAL CONCEPT

The Shop Assembled Modular Boiler utilizes the well-proven concept of the factory assembled package boiler used so extensively in American industry. This arrangement maximizes the number of integral parts to be shop-assembled, and minimizes field erection and associated higher installation costs. The furnace must be shipped in large assembled modules rather than as a complete unit when capacities exceed 60,000 to 70,000 lbs/hr of steam generated. The furnace envelope required to fire solid fuels is approximately three to four times greater than what is recommended when firing oil or gas.

There are four major components that are completely assembled in the shop; the stoker, furnace, superheater, and the boiler bank modules. Figure 1 depicts this modular concept. The sequence for erection of these components is as follows: structural frame, stoker, furnace, superheater and boiler bank.

Downcomers, feeders, and releasers are installed last. The furnace module is of welded wall construction with all headers attached, observation doors installed, and all integral buckstays welded in the shop to comply with all the latest code requirements. (See Figures 2, 3, and 4.) Special fixtures are built to support the main drum and the mud drum in the shop so as to allow for complete assembly before shipment. The same concept applies to the superheater module. These special fixtures are reusable on future installations, therefore, substantially reducing initial cost.

Presently under construction for the Georgia Pacific Corporation at Fort Bragg, California, is a 140,000 lbs/hr steam generator with outlet steam conditions of 400 psig and 725°F.

This installation is fired by redwood bark and Number 5 oil. This facility demonstrates the shop assembled modular concept, and will be in commercial operation later this year. See Figure 5.

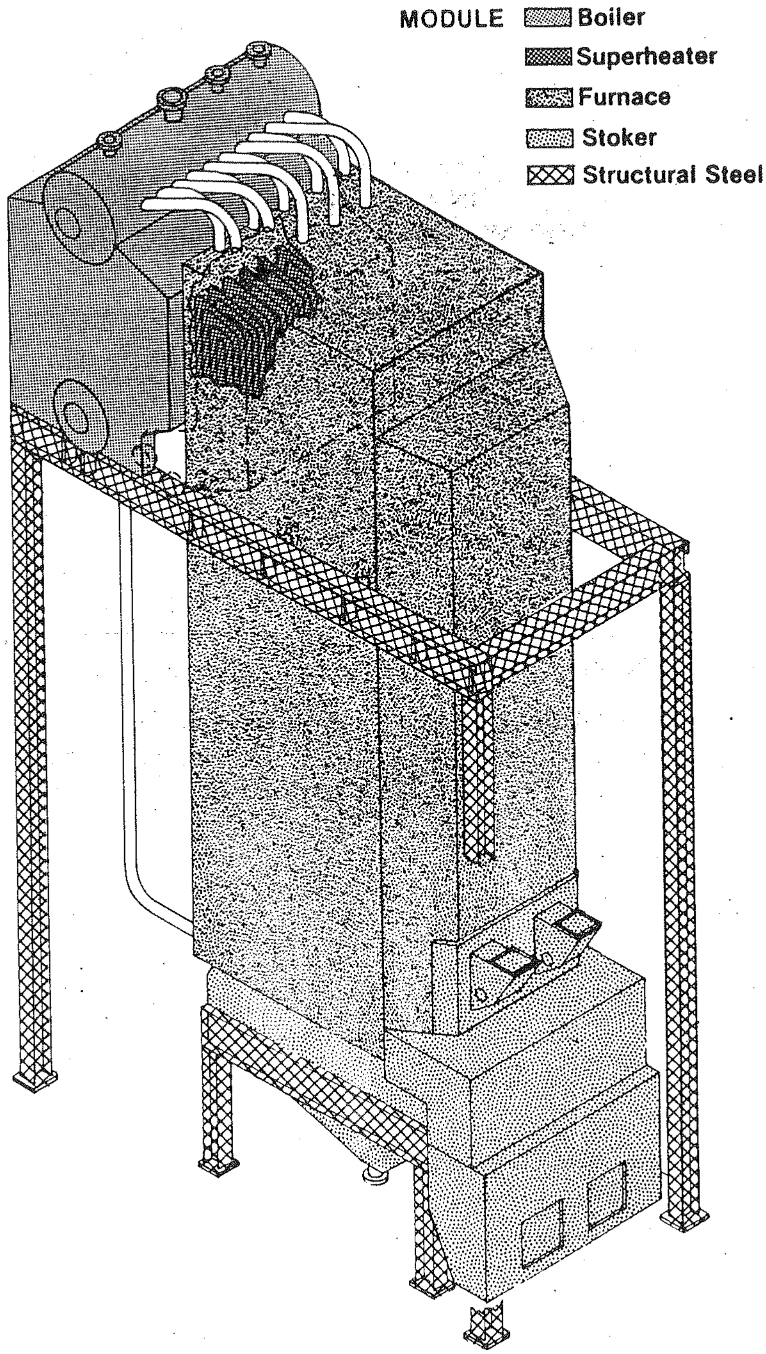


*Figure 1 Isometric View of Shop Assembled Modular Boiler*

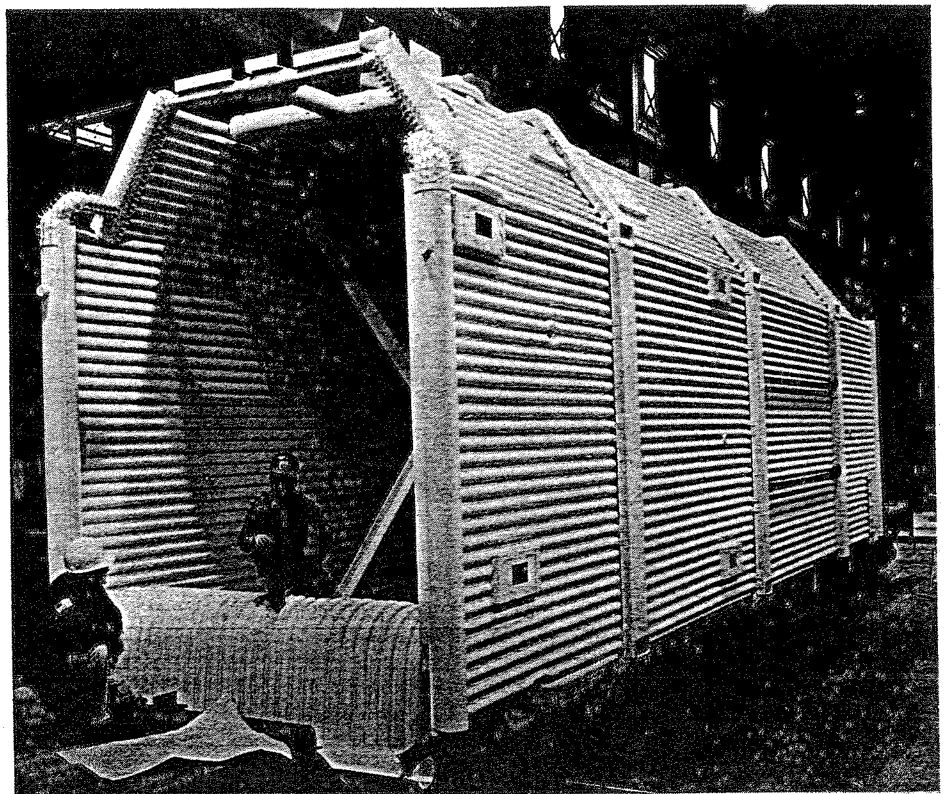

*Figure 2   View From Rear of Furnace Module Ready for Shipment*

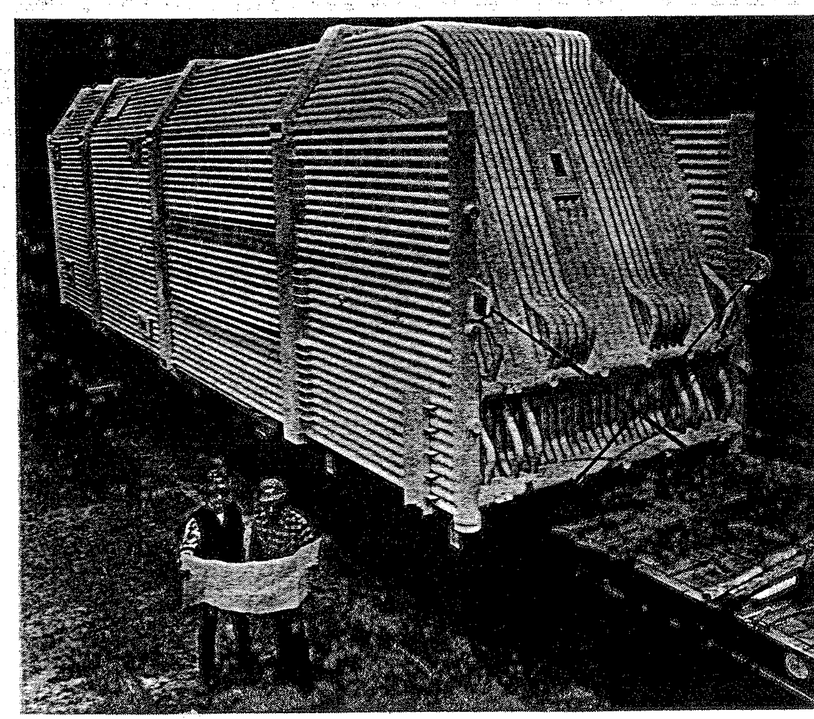

*Figure 3   View From Top of Furnace Module Ready for Shipment*

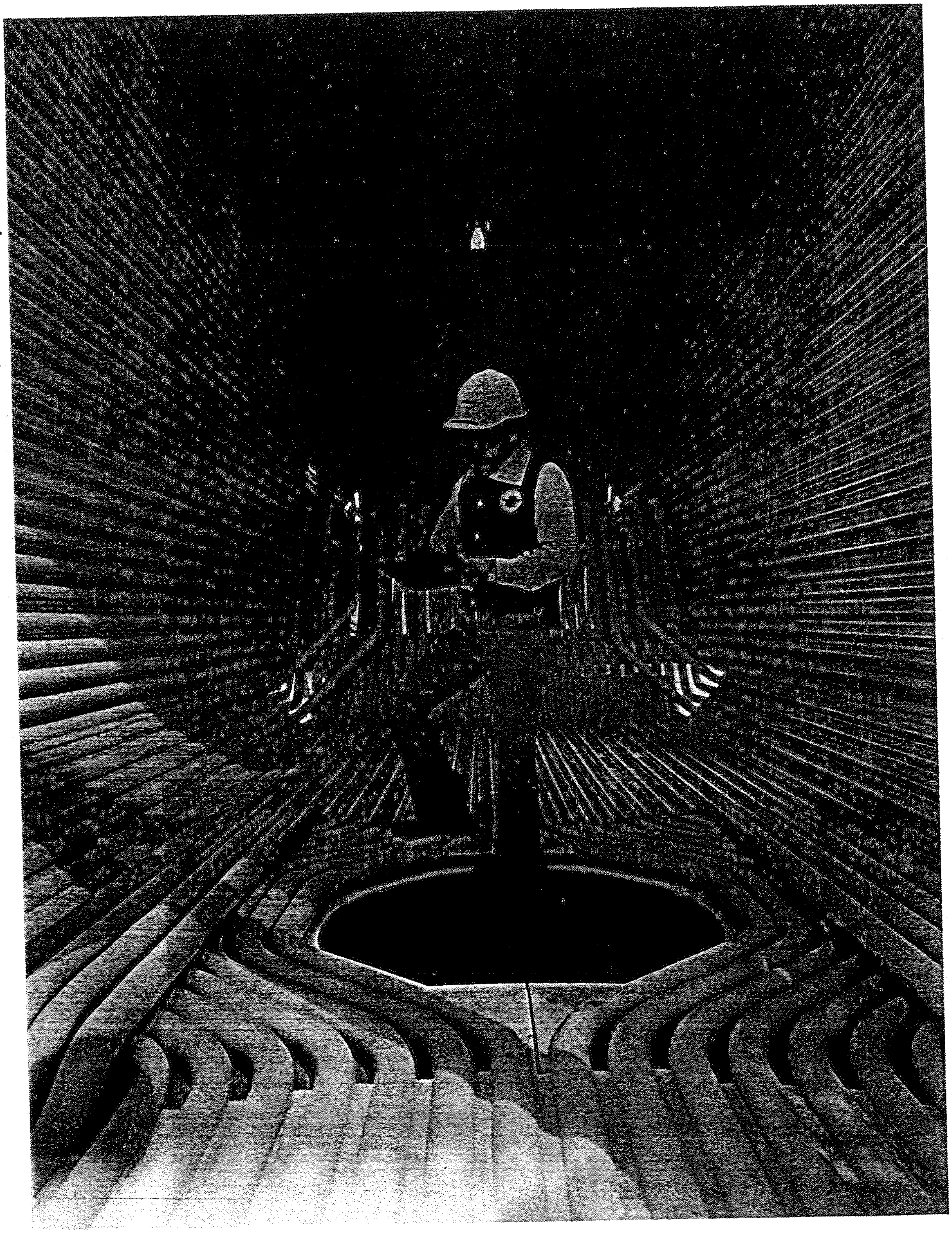

*Figure 4 Internal View of Furnace Module and Burner Opening*

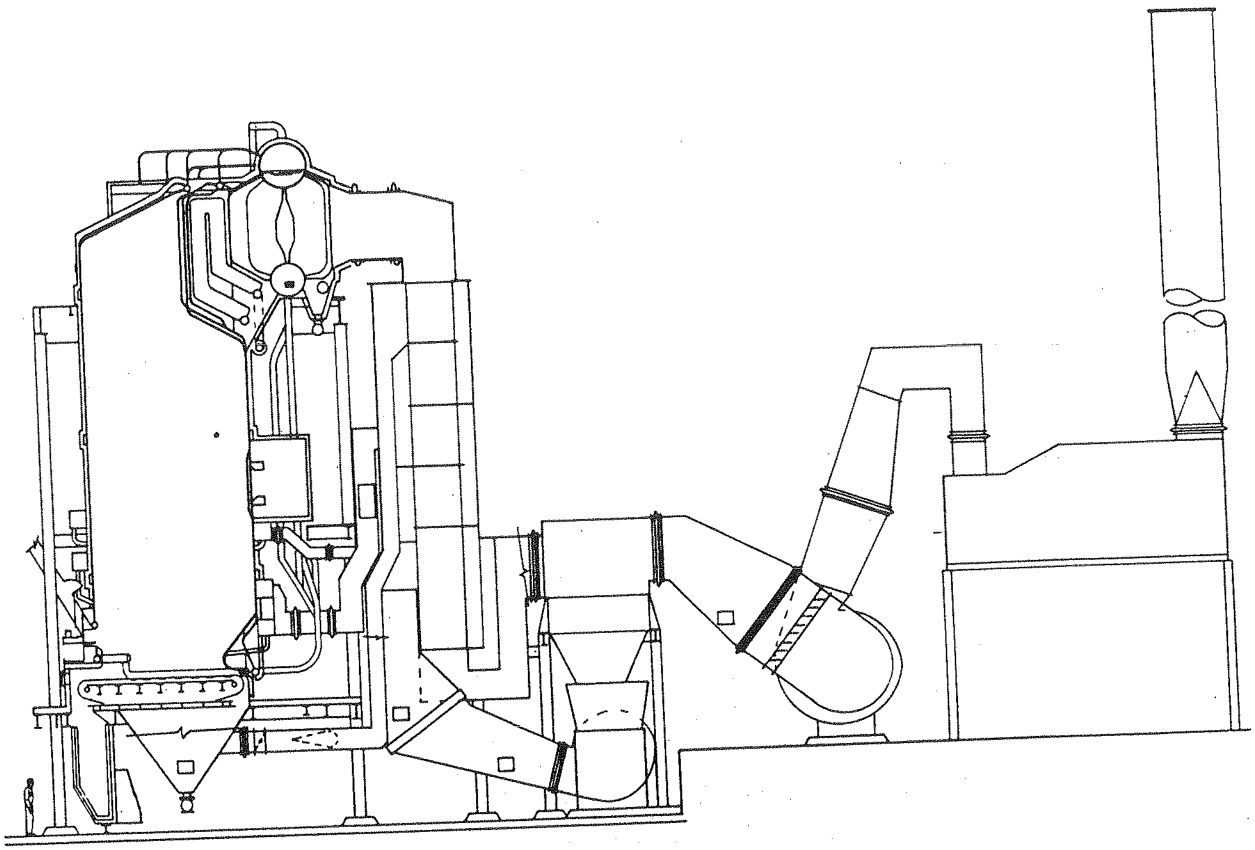

*Figure 5 Sectional Side Elevation,*
*Shop Assembled Modular Spreader Stoker Boiler Firing Wood*

## BENEFICIAL CONSIDERATIONS

The modularization concept brings about many desired advantages to the industrial user. These can be broken down into three major categories as follows:

1. Lower overall cost
   a. Engineering design is common for most applications due to the standardization and duplication of arrangements.
   b. Field erection cost is minimized since most of the assembly operations take place at the manufacturing facilities.
   c. Manufacturing operations are simplified by the constant reuse and updating of proven methods. A great degree of continuity is achieved due to uniform configurations.
2. Reduced overall time to completion
   a. Field corrections are substantially diminished since most components have already been fitted during the shop-assembly operation.
   b. The handling of materials is simplified due to the availability of storage facilities.
   c. All construction fixtures required for shop assembly operations are completely reused in future applications.

3. Improved quality control

   a. It is possible to develop a well structured manufacturing program since all operation procedures are constantly reutilized.

   b. The work crews can devote all of their time to their field of expertise.

   c. All of the assembly operations are performed under complete and expert supervision.

   d. Continuous improvements are made to the design and manufacturing of all components since no additional time has to be spent on re-designs.

## DESIGN FLEXIBILITY

*Furnace Selection*

There are many parameters involved in the selection of furnace configurations. It would seem that the logical tendency is to select an oversized furnace that will provide the highest possible degree of conservatism. If this is the case, unfortunately, we will not only have an uneconomical design, but we can also be faced with a system that has inadequate heat content in the flue gas. Sufficient energy in the system is imperative to achieve the desired degrees of superheat; however, too small a furnace can also present major adverse conditions such as too much slag accumulation on furnace walls and convection section, tube burn-outs, excessive particle carryover, carbon loss, and short component life.

| | | | | HEAT RELEASES | | | |
|---|---|---|---|---|---|---|---|
| | | | | | | GRATE SURFACE BTU/HR FT² | |
| | FURNACE EXIT GAS TEMP., °F | VELOCITY FT/SEC | VOLUMETRIC BTU/HR FT³ | RADIANT SURFACE BTU/HR FT² | TRAVELING | WATER COOLED | HOPPER FED |
| BITUMINOUS COAL | 1700 | 55 | 18,000-27,000 | 75,000 85,000 | 700,000-850,000 | — | 450,000 |
| SUB-BITUMINOUS COAL (LIGNITE) | 1700 | 55 | 15,000-25,000 | 70,000-80,000 | 700,000-850,000 | — | 425,000 |
| CELLULOSE FUEL (BAGASSE, WOOD LOW SAND CONTENT) | 1650 | 50 | 18,000-27,000 | 90,000 | 1,000,000 | 1,000,000 | — |
| CELLULOSE FUEL HIGH SAND CONTENT | 1625 | 40 | 25,000 | 80,000 | 1,000,000 | 1,000,000 | — |

**Note: The values and ranges shown above are maximum limit guidelines and some deviations can occur without adverse effects in the unit operation.**

*Table I Tabulation of Recommended Boiler Design Parameters*

Table I depicts recommended boiler design parameters employed when firing solid fuels on traveling and stationary grates. One of the most important indicators as to whether or not the furnace has been properly sized is the effective projected radiant surface heat release. The ranges shown are only guidelines; some deviation can occur without any adverse effect on the operation of the boiler. It is necessary to increase the size of the furnace to accommodate higher fuel rates, caused by lower heating values and higher moisture contents, in order to properly fire lignitic-type fuels. This concept is represented in Table I by a lower range of heat releases when firing sub-bituminous coal as compared to the bituminous values. Lignitic type fuels also have slagging tendencies which are much more severe than most bituminous coals; consequently, more cooling surface is recommended. Because of the low ash content and slagging tendencies, higher heat releases are permitted when cellulose fuels are fired. The large amounts of flue gas caused by the very low heating value and very high moisture contents maintains approximately the same furnace exit gas temperature, even though the furnace envelope as been substantially reduced. The different radiation flame characteristics play a very important role on the furnace exit gas temperature levels. The volumetric heat release follows the same trend, but is not used as such an important parameter in furnace design.

Grate heat release rates are maintained within the ranges shown in Table I in order to minimize the amount of flyash, carbon loss, and carryover. In recent years, it has been demonstrated that, with grate heat releases up to 1,000,000 Btu/hr/sq. ft. when firing cellulose fuels, we can achieve excellent combustion efficiencies. We can successfully accomplish this by using several levels of overfire air nozzles with quantities approaching 50 percent of combustion air. Grate heat releases up to 850,000 Btu/hr/sq. ft. can be achieved when firing coal by increasing the amount of overfire air introduced at higher levels in the furnace. The shop assembled modular construction does not restrict, in any manner, the ability of maintaining complete furnace design flexibility.

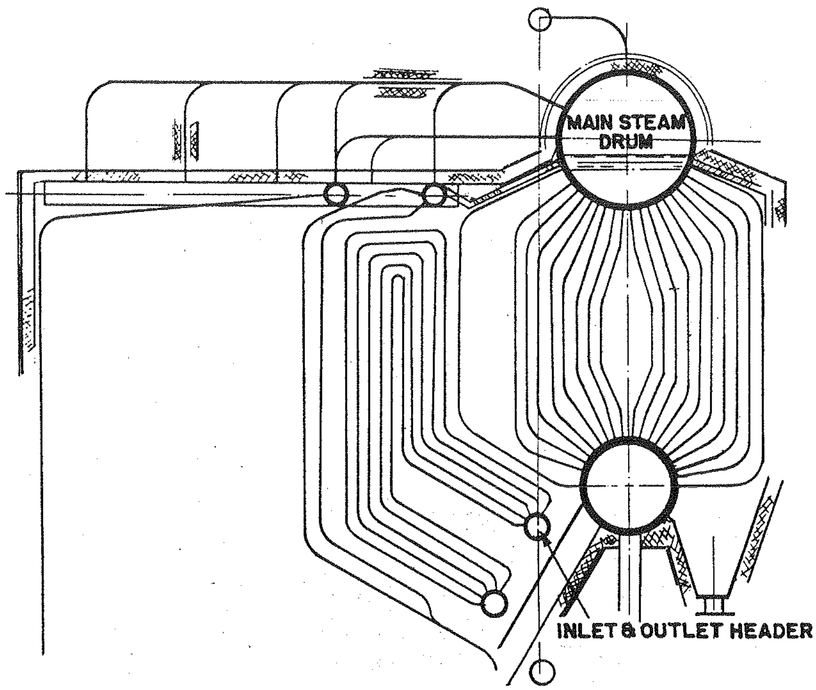


*Figure 6 Typical Drainable Superheater Arrangement*

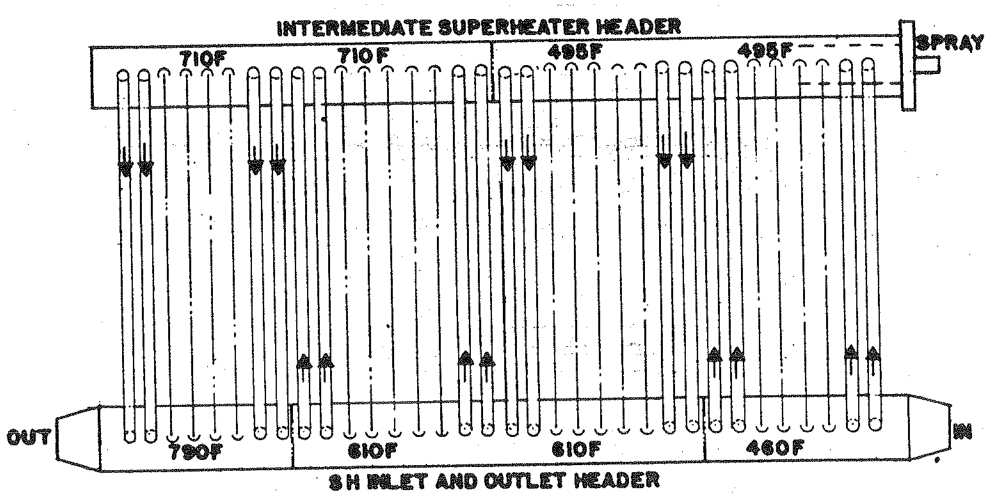


*Figure 7 Schematic for Header Arrangement, Drainable Superheater*

*Superheater Configurations*

Specifications, requirements, and customer preferences demand complete flexibility of superheater arrangement. On Figure 6 we show a drainable superheater modular arrangement to be inserted through the back of the furnace module. This superheater can provide steam temperatures up to 750°F. The transversal tube spacing is completely adjustable during the design stages to accommodate any type of high-fouling fuel. We can adjust the steam mass flow and pressure drop to give us proper distribution and adequate heat transfer coefficients by strategically locating partition plates in the superheater headers. (See Figure 7) A spray attemperator can be installed in the intermediate superheater header, or a mud drum heat exchanger can be utilized for controlling steam temperatures. This superheater arrangement has been used extensively on oil and gas-fired packaged boilers.

Figure 8 shows a typical pendant, non-drainable type superheater to be inserted from the roof. This configuration lends itself nicely to future heating surface addition subsequent to initial operation or plant cycle change with minimum field work. It also can achieve steam temperature levels up to 800°F.

Figure 9 shows a combination of radiant and convective type superheater capable of reaching steam temperatures in excess of 900°F. This type of arrangement provides great flexibility for future additions of heating surface. The convective superheater can be installed through the rear of the furnace module. All of the above systems, even though they are used in conjunction with the modular concept, are technologically proven designs used for many years.

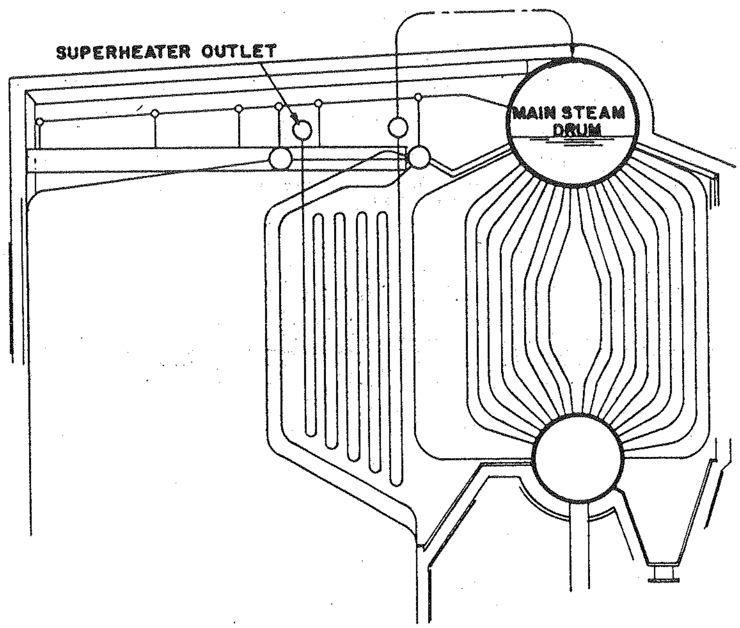


*Figure 8 Typical Non-Drainable Superheater Arrangement*

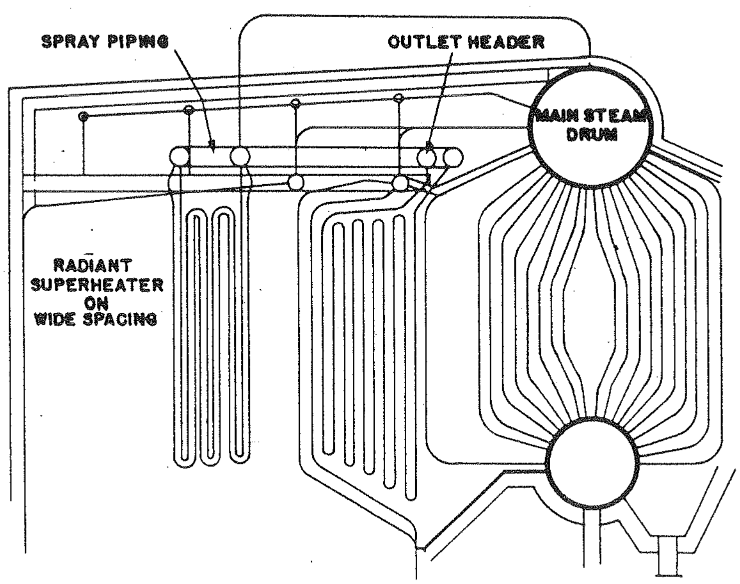


*Figure 9 Typical Non-Drainable Radiant and Convection Superheater Arrangement*

*Convection Bank Arrangements*

Probably one of the most important parameters in boiler design is the selection of transversal spacings and open areas in convection type superheaters and boiler banks. Bituminous and sub-bituminous coals with high concentrations of sodium oxides in the ash will cause severe deposits in the face of the tubes, which can eventually bridge across or drastically restrict the flow of flue gas.

When firing cellulose fuels, the concern is of a different nature. Hogged wood, bagasse, and other cellulose fuels contain large quantities of sand which can cause severe erosion and abrasion-related equipment failures. The tube bundle velocities must be drastically reduced in order to minimize the possibility of tube erosion.

In order to preclude bridging and to reduce gas velocities, clear spacing between the surfaces of the tubes must be increased when firing severe fouling coals. The velocity of impingement of the gas particles has a remarkable effect on its capability of adhering to the tube surface. Lower velocities are also recommended in this instance.

Recommended bundle clearances for different fouling tendencies as a function of gas temperatures are shown on Figures No. 10, 11, and 12. A typical design is superimposed so as to clearly emphasize the conservative design. A typical convection bank arrangement with gas velocities, temperatures, and tube clearances is analyzed for three different types of fuels; low fouling bituminous, high fouling bituminous or sub-bituminous coal, and severe fouling lignite.

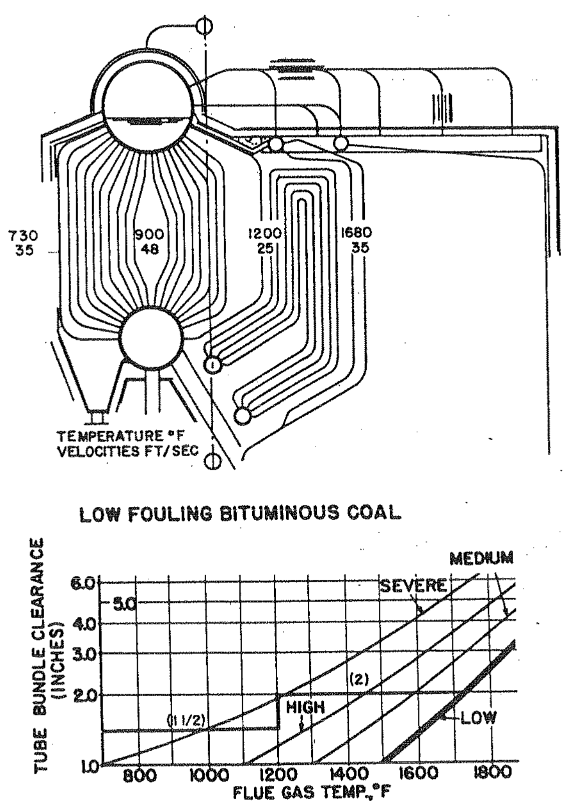


*Figure 10 Recommended Tube Bundle Clearances for Low Fouling Coal*

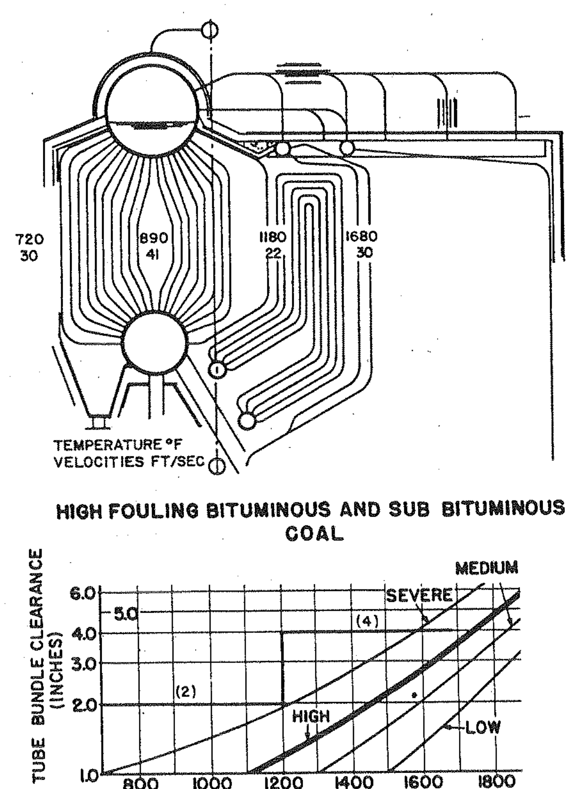


*Figure 11 Recommended Tube Bundle Clearances for High Fouling Bituminous and Sub-Bituminous Coal*

In general, it can be observed that the levels of gas temperatures and velocities are reduced, and the tube clear spacing increased with higher fouling tendencies.

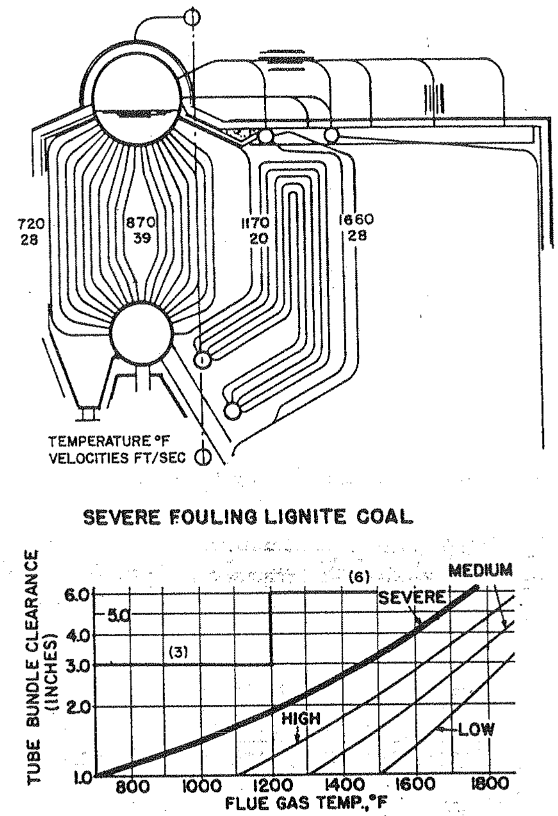


*Figure 12 Recommended Tube Bundle Clearances for Severe Fouling Lignite*

Figure 13 shows a typical convection arrangement designed to fire hogged wood with a low sand content. The tube spacing can be substantially reduced and the velocities increased without affecting the unit performance. The shop-assembled modular concept allows complete velocity, gas temperature and spacing flexibility, thus permitting the successful combustion of the different fuels fired.

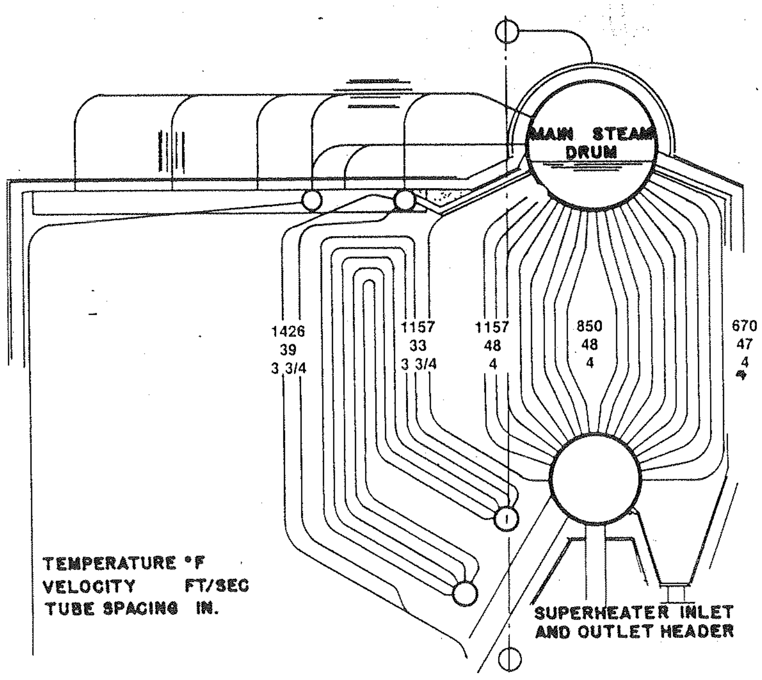


*Figure 13 Typical Wood Fired Arrangement*

Figures 14 and 15 show, respectively, two typical arrangements of a water-cooled grate and a mass-fed traveling grate coupled to a Shop-Assembled Modular Boiler. The water-cooled grate is utilized when burning bagasse and many types of hogged woods. The mass-fed traveling grate has been used for many years to fire fuels with a wide range of coking, caking and ash fusion temperatures (fine sizes of anthracite, coke breeze lignite, bituminous, and sub-bituminous coals). The traveling grate spreader stoker is commonly used for most applications. Auxiliary burners can be added to any of the firing systems described above.

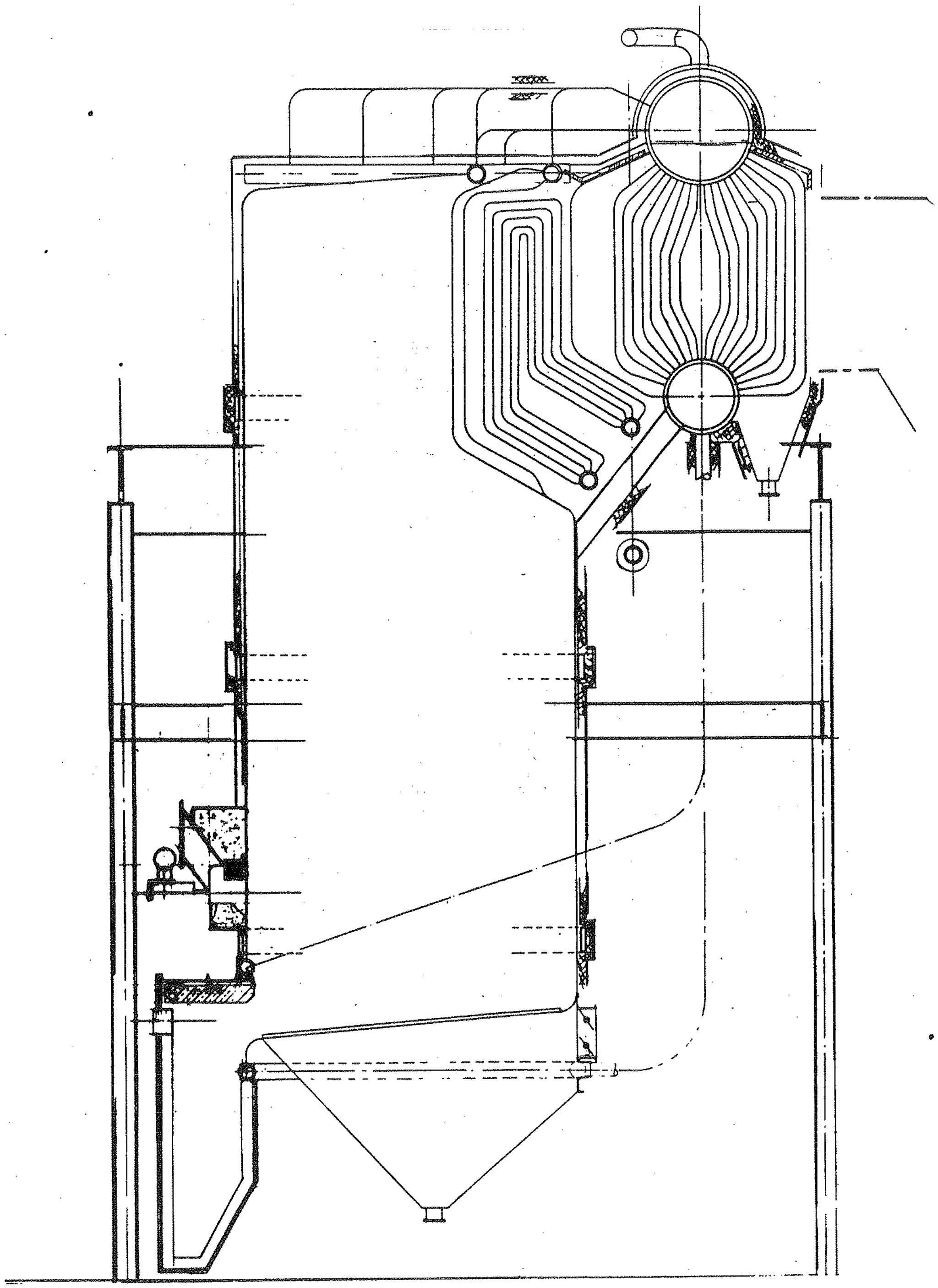

*Figure 14 Shop Assembled Modular Boiler Fired by a Stationary Water Cooled Grate*

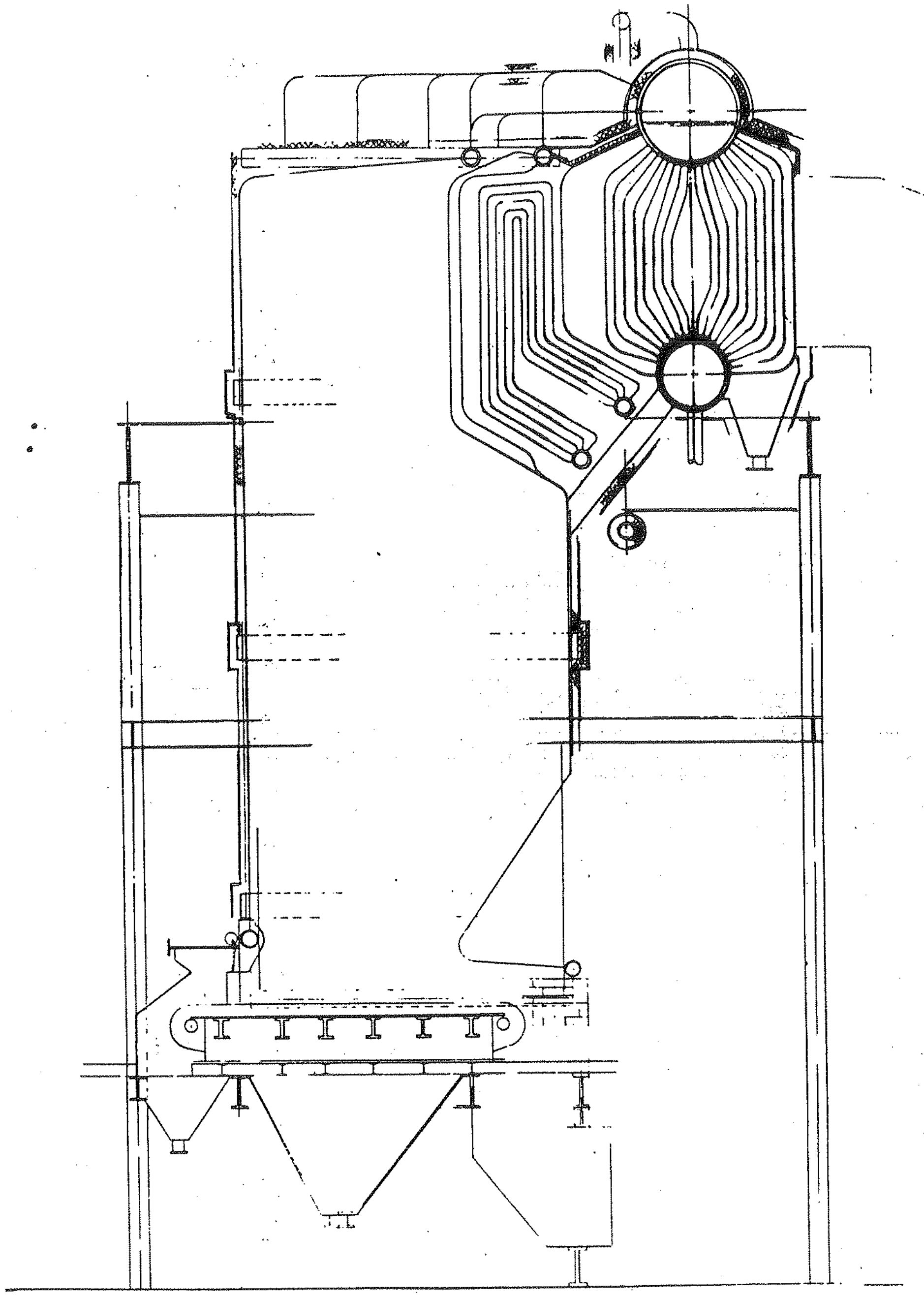

*Figure 15 Shop Assembled Modular Boiler Fired by a Hopper Fed Traveling Grate Stoker*

## CONCLUSION

Government regulations, customer requirements, and fuel availability will ultimately force the boiler manufacturer to continuously provide the American industry with new designs.

Flexible furnace designs, superheater configurations, convection arrangements, and firing systems allow the designer to meticulously select all parameters that constitute the state of the boiler makers' art. The Shop Assembled Modular Boiler concept does not compromise good engineering practice; it does, however, couple proven design experience with complete design flexibility, thus providing the industrial user with a very economical alternative.