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Some ten years ago a large manufacturer in New England was approached with a proposal for materially bettering his fuel practice. The proposal was rejected on the grounds that coal represented less than 10 per cent of the cost of production, that a 10 per cent saving on this meant a saving of less than 1 per cent on the whole operation, and that economies of far greater consequence had prior claims to attention—in short, that the power plant was the least source of worry. Since then, however, this particular plant, in search of relief from its coal troubles, installed an oil burning equipment only to get caught in the rise of fuel oil prices and revert to coal, and on at least one occasion has been entirely shut down for lack of fuel.

The case is fairly typical and serves to bring out two points of fundamental importance: (1) That the fuel question has grown to be of major significance and (2) that its growth has been so rapid—largely within the last decade—that there scarcely has been time to work out the answer in standard form available to the average user. Thus, while consumers in general have come to appreciate these changing conditions to a greater or less degree, they have not been uniformly in a position to cope with them.

Power plant operations large enough to have the benefit of their own expert advice are able to work out the answer to their particular problems and are reasonably up to date in the way of equipment and operation. The average consumer, however, having no expert advice to bring to bear upon his problem, is dependent upon established practice, and in the absence of standards is still operating in the dark. The object of this writing is to bring out to what extent the average consumer may reasonably expect to profit from available data.

THE FURNACE A CHEMICAL PLANT

Combustion is a chemical reaction and a furnace is in reality a chemical plant manufacturing heat units. As such, the furnace operation falls into the same category with any other chemical process which, to be effectively operated, is at all times concerned with three important factors:

(1) The use of proper ingredients,

(2) In the proper proportions,

(3) Under the proper conditions.

By this is meant using the right coal under adequate furnace control and with the proper design of furnace installation. More specifically, the three issues involve: (1) The quality of coal, (2) furnace control, and (3) furnace installation, and will be taken up for discussion under these three general headings, but in reverse order.

FURNACE INSTALLATION

The manufacture of furnaces and boilers is a major industry in itself, composed of large organizations engaged in active competition and each having its own corps of highly trained experts. Exhaustive studies of combustion and heat absorption have been made not only under research conditions but under operating conditions as well. As a result, furnace and boiler designs have been developed which may be taken as embodying the best principles and suited to all ordinary requirements. This being the case, in the matter of furnace installation the consumer need scarcely concern himself beyond determining whether it is of standard design, reasonably up to date, and reasonably in keeping with the requirement.

FURNACE CONTROL

To appreciate the need for furnace control it is necessary to understand something of what takes place within the furnace. Reference has already been made to the combustion of coal as being a chemical reaction. Precisely speaking, it includes a number of reactions, involving the several ingredients composing coal, but inasmuch as carbon is the major ingredient, in the interest of simplicity, attention will be confined to its activity within the furnace.

When carbon burns it unites with the oxygen of the air in two ways. Expressed chemically, these are

$$C + O_2 = CO_2$$

and

$$2C + O_2 = 2CO$$

which means, taking into account the relative weights of the ingredients involved, that in the first reaction,

(1) 12 parts carbon + 32 parts oxygen = 44 parts carbon dioxide gas (a ratio of 1 carbon to 2.7 oxygen),

and in the second,

(2) 12 parts carbon + 16 parts oxygen = 28 parts carbon monoxide gas (a ratio of 1 carbon to 1.3 oxygen).

Chemical science has established the fact that the relationships expressed in reactions (1) and (2) are invariably fixed; for instance, that 12 parts of carbon requires exactly 32 parts of oxygen, forming exactly 44 parts carbon dioxide gas. Furthermore, the heat evolved in these combinations is a constant quantity. The heat evolved in reaction (1) is, however, over three times greater in amount that that evolved in reaction (2) for the reason that the former is the result of complete combustion. As a matter of fact, the carbon monoxide gas formed in reaction (2) can be ignited in the presence of air, and in the process of its combustion is converted to carbon dioxide. The heat released by this reaction added to that of reaction (2) will be equal to that released by the complete burning of carbon to carbon dioxide, as shown in reaction (1). Unburned and allowed to escape up the chimney, it means just so much coal (about two-thirds) wasted, or a 450 B. t. u. extraction from a 1350 B. t. u. coal. Yet it is not at all uncommon for a consumer to haggle over a variation of 50 heat units in the coal furnished him without giving the least heed to what is going up the stack.

Let us consider the matter of fixed relationships of ingredients a little further. If instead of supplying the exact amount of oxygen as called for in reaction (1), more is supplied, then, on the basis of chemical law,

(3) 12 parts carbon + 50 parts oxygen = 44 parts carbon dioxide gas + 18 parts uncombined oxygen (a ratio of 1 carbon to 4.2 oxygen),

while if less oxygen is supplied than theoretically required, the reaction would be

(4) 12 parts carbon + 20 parts oxygen = 8 parts carbon dioxide gas + 24 parts carbon monoxide gas (a ratio of 1 carbon to 1.8 oxygen).

Comparing reaction (3) with reaction (1) it will be noted that while the carbon consumed, and hence the heat generated, remains the same, the resultant gases have been materially increased in volume. When we consider further that the addition of 18 parts of oxygen, since it is introduced in the form of air, carries with it another 72 parts of nitrogen, the increase in volume is seen to be decidedly significant. One result is to lower the working temperature within the furnace precisely as the introduction of cool air into a room lowers the room temperature. Another ill effect is that since the flue gases carry off heat, any material increase in the volume of flue gases gives a correspondingly significant increase in the heat thus escaping.

Analyzing the results in reaction (4), it develops that only one-fourth of the carbon has been fully burned, the other three-fourths being two-thirds wasted; in other words, there has been only a 50 per cent extraction of heat units.

In short, adequacy of results is to be attained only as the requirements of exact chemical laws are met with exactitude. Deviations resulting in as much as 50 per cent loss in efficiency may easily go unnoticed in the absence of any definite check in the way of chemical control. As a matter of fact, it is not too much to say that modern industry is built around chemical control, and it is a striking fact that the one chemical process involving, in the aggregate, the largest capital outlay remains to-day largely subject to rule of thumb methods.

Domestic Application

The principles underlying effective combustion apply to the household furnace and to the power house installation alike. There is this difference however: In the former the furnace receives only casual attention and that of a perfunctory, inexpert nature, while the latter is being constantly ministered to by specially trained attendants. Accordingly, the smaller installations are subject to a handicap which prevents any rigorous application of chemical control, but this does not mean that an intelligent application of the general principles may not be made productive of significant results, especially in view of the present high fuel costs. It is not at all uncommon to encounter one consumer burning twelve or fourteen tons of coal while another operating under essentially similar conditions gets by with six or eight tons. Discrepancies such as these indicate conclusively the extent to which irregularities in practice may lead to readily preventable losses.

The general principles of effective combustion in substance boil down to having the furnace in good working order; exercising effective draft control; and using the coal best suited to the requirement. The defect most commonly encountered in the upkeep of the furnace itself is that of dirty flues. A one-eighth inch coating of soot provides an insulation which will cut the absorptive power over 25 per cent. The flues should be cleaned in the case of anthracite at least every few weeks and in the case of bituminous coal practically every day. Other defective developments commonly met with are in the form of leaky settings, cracks, warped castings, and the like. These, however, communicate their ill effects chiefly in the matter of draft control and may therefore be considered under that head.

In this latter connection, two general deductions are to be derived from what has been said in the preceding pages. First, that air entering the furnace above the fuel bed is objectionable in that it serves to lower the temperature within precisely as the influx of cold air lowers a room temperature. Second, an undue amount of air beyond that required for combustion, even when fed through the fuel bed, is open to the same objection. Accordingly, the common practice of opening the coaling door or even the slide in the door to check the fire is, in general, bad and should be resorted to only when absolutely necessary; similarly, holes or cracks admitting air above the fuel bed should be sealed as soon as they develop.

As too much air passing through the fuel bed has the same general effect as air fed over the bed, it follows that the further practice commonly met with of opening the ash pit door to obtain full draft is scarcely less objectionable than opening the coaling door, and leaky settings, cracks, etc., leading into the ash pit, in their general effect, are not unlike similar defects in the combustion chamber. So far as possible, the control over the furnace should be accomplished with the check damper, supplemented by the opening of the ash pit damper only to a sufficient degree and for a sufficient time to stimulate combustion. In this way excess air with its consequent cooling effect is cut to a minimum and the course of the gases is retarded, giving the maximum opportunity for the heat to be absorbed. One of the commonest practices met with combines about everything that has been pointed out as objectionable. This is the practice of banking the furnace at night leaving the coaling door open, to be followed in the early morning by opening up everything down below. This means the complete loss of the heat generated by combustion during the night followed by the cooling effect of excess draft throughout at least the early part of the day.

The value of having a coal uniformly suited to the requirement will be discussed in some detail later. It may be well here, however, to touch briefly on the important bearing that the size of coal exerts. The case comes to mind of a householder accustomed to using nut coal but forced under the stress of shortage to burn egg. His coal requirement became so excessive as to prompt investigation. This revealed that to start with, he used the same draft in the case of egg as with nut, but, failing to obtain the requisite heat, he opened the draft still further. This failed to help matters so he ended by keeping all drafts wide open and reconciled himself to the thought that the coal was deficient in heating value. It need scarcely be pointed out that the trouble lay in the fact that the larger size of coal gave free passage to the cold air which kept down the temperature in the combustion chamber and caused the hot gaseous products of combustion to pass directly into the chimney.

What has been said in the foregoing paragraphs relative to the domestic furnace operation applies directly to the use of anthracite coal and along with it the use of coke, its artificial equivalent, which has already made a considerable place for itself and is due for further extension. In using bituminous coal the slide in the coaling door should be left open to provide air for burning the volatile matter and closed immediately thereafter. A further difference of treatment desirable in the case of bituminous is that of firing on one-half of the fuel bed at a time, so as to always maintain a live combustion surface necessary to ignite the volatile matter. Adherence to this special procedure may be made to yield results for low volatile bituminous coals comparable to the use of anthracite, in the matter of smoke.

Industrial Application

As coal consumption reaches the stage of tons per day, the attention paid to the furnace becomes practically continuous so that any apparatus which can indicate or guide the operator in the control of the process of combustion can be effectively utilized. In this connection, a report of the United States Fuel Administration, covering the period from September 1, 1917, to March 1, 1919, contains the following passage:

> The average steam user in the whole United States knows but very little in detail about the operations of his steam plant or its economic possibilities. This has been largely due to the fact that coal has been cheap and in great quantity, and usually this department has been a small one compared to others. They are beginning to see, however, that a dollar saved in this department is worth as much as a dollar saved in any other, and we believe that in the near future the power department of the average manufacturing establishment will be given the same attention as any other department. The questionnaires returned to this office show that *ninety-five per cent* of the steam users have but the *faintest idea of their actual steam* costs, and these plants, as a general thing,

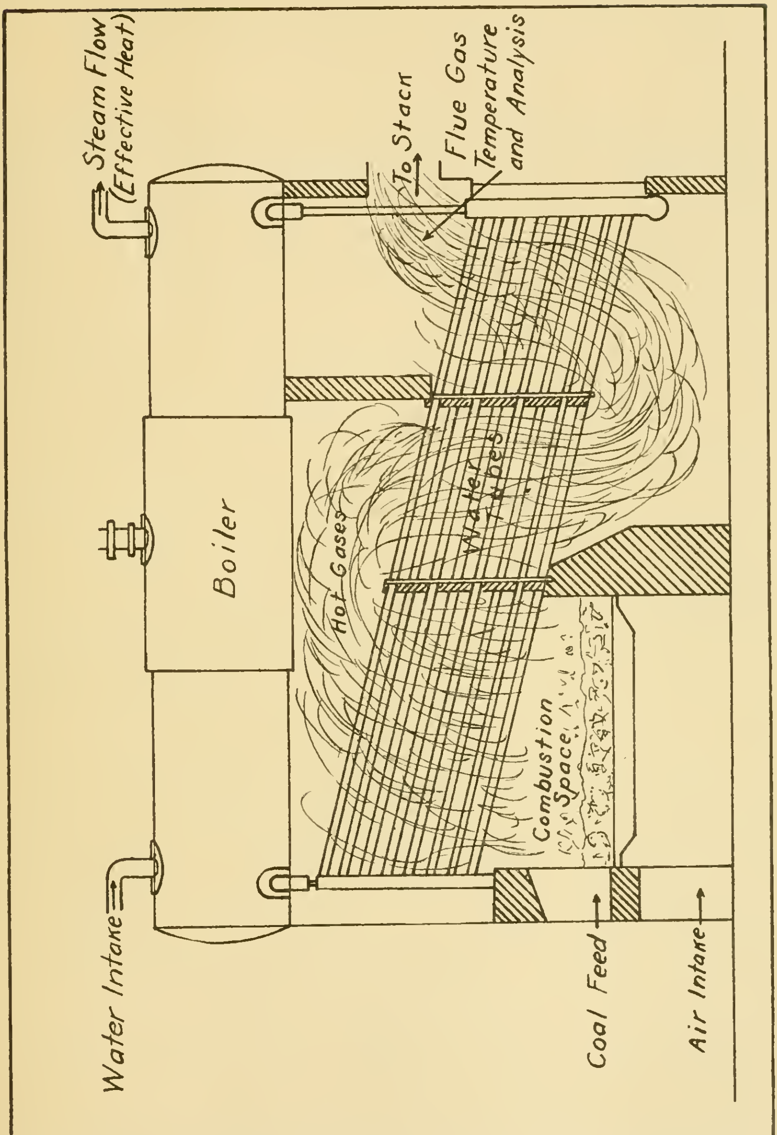

FIG. 1.—Working Principles of the Ordinary Industrial Furnace.

are still *run under the realm of guess-work.* Even some of the larger plants that are well equipped with various instruments to determine the efficiency of their plants and their unit cost of steam are operated with such an inferior class of help and with no intelligent supervision that these advantages are entirely lost.

Page 7 gives a graphic representation of the combustion reactions applied to industrial furnace practice. The coal fired on the grate plus air in the form of draft yields carbon dioxide in the form of waste gas plus or minus free air or free carbon monoxide gas, depending upon how the ideal reaction (1) has been approached. It will be noticed that the hot gases from combustion are forced to take a roundabout course on their way to the stack by the introduction of a series of baffles. This is to give the maximum opportunity for the boiler tubes to absorb the heat. In spite of this, the gases are still hot as they enter the chimney which means that they carry away a very appreciable amount of heat. Too much air fed in as draft results in an unnecessary volume of gases and a correspondingly preventable loss of heat. Insufficient air affords insufficient oxygen, resulting in incomplete combustion forming carbon monoxide instead of dioxide and the carrying off of two-thirds of the heat units as lost potentiality.

Two general lines of procedure suggest themselves for subjecting the industrial furnace to chemical control, namely, measuring the raw materials, coal and air, and measuring the results. The first named is impractical, if for no other reason than that of the ever varying composition of the coal, as will be discussed more in detail later. The second line of procedure, that of measuring the results, may seem, offhand, open to the objection of locking the door, as it were, after the horse is stolen. Given an indication of satisfactory versus unsatisfactory results, however, we are in a position to gage our procedure accordingly. This brings to mind the relationship already brought out, to the effect that the best results are, in general, attendant on the highest percentage of carbon dioxide in the flue gases, and points at once to the importance of flue gas analysis as a medium of control. Along with this, the importance of steam flow measurement is self-evident inasmuch as steam is what is most desired. These two together afford a check against one another in the determination of results and the fixing upon the procedure best calculated to bring them about. All that now remains is to interpret these results in terms of the conditions existing in the furnace and provide a means for maintaining those conditions uniformly. Thus with the co-ordination of three sets of records we are in a position to subject the whole operation to definite chemical control. These three will now be taken up in turn for discussion.

Steam Flow Measurement

Experience reveals the surprising fact that the average operator, more particularly the smaller operator, has not the remotest conception as to how much steam he is securing, in other words, whether he is operating on an efficient basis of seven or eight pounds of steam per pound of coal or whether he is getting only four or five pounds. Accordingly, taken by itself a steam flow indicator is a first requisite to enable the operator to be cognizant of conditions and the possible room for improvement. Its further function as an adjunct to the fitting control of furnace practice has already been brought out.

The steam flow meter is applied to the steam outlet of the boiler and in its simpler form will indicate on its dial the momentary output of steam. There are several types of flow meters made, all of which, however, are designed fundamentally on the Pitot tube or the Venturi tube principle. Whatever the type, the meter is installed in the steam line and the steam in passing through the mechanism produces a differential pressure which is proportional to the square of its velocity or rate of flow. Any change in pressure actuates the indicating hand on the meter dial, the readings on which may be in pounds per hour or in horsepower.

Flue Gas Analysis

Thanks to the efforts of scientists, the chemistry of gases, and particularly their analysis, has been resolved into quite a simple procedure. There are several ways in which gases may be analyzed, depending upon one or another of the properties of the individual compounds composing them as, for instance, the differences in refractive power of the constituents, and again, the power of certain chemical reagents to select and absorb one of the several compounds. A familiar application of this latter principle is the gas mask used during the war, in which a certain reagent is used to absorb the poisonous constituent of the war gas before the air containing it is breathed into the lungs. It is this same principle that is most generally used in the analysis of flue gases, and while the several types of apparatus used to make analyses by this method may vary as to detail, they are simply modifications of the apparatus devised about 50 years ago by the French scientist, Orsat.

We have seen earlier that the significant gases which may pass up the stack of a furnace are carbon dioxide, oxygen, and carbon monoxide. To analyze such a gaseous mixture by the Orsat method means simply to bring about the absorption of each one of the constituents and determine by the resultant changes in volume the percentage composition. A solution of caustic potash will absorb carbon dioxide but neither oxygen nor carbon monoxide; further, a solution of pyrogallic acid and caustic potash will absorb oxygen; and lastly, an ammoniacal solution of cuprous chloride will absorb carbon monoxide. These are the reagents used. Figure 2 shows a simple form of Orsat apparatus. The graduated bulb on the right measures a unit quantity of the flue gas to be analyzed; the three bulbs to the left contain the several absorption reagents; that one immediately adjoining the graduated bulb absorbs carbon dioxide; the next to the left absorbs oxygen; and the last absorbs carbon monoxide. In operation a measured quantity of flue gas is admitted into the graduated bulb, and by means of simple valves and the leveling bottle shown, the gas is forced into the carbon dioxide absorption bulb; here it is allowed to remain for a time, during which the carbon dioxide is absorbed by the caustic potash, after which the gas is drawn back to the graduated bulb and the difference in volume resulting represents the percentage of carbon dioxide originally present. In a similar way the percentage of oxygen is determined after the carbon dioxide has been removed from the gas, by absorption in the second bulb. Finally, after the removal of both the carbon dioxide and the oxygen, the percentage of carbon monoxide is determined by absorption of the remaining gas in the third bulb.

With a hand analyzer such as shown, the percentage of carbon dioxide may be determined in the short space of a minute, but to determine oxygen and carbon monoxide in addition to carbon dioxide, will require about 15 minutes. We have seen earlier, however, that a knowledge of the percentage of carbon dioxide alone is extremely helpful in bringing about a good furnace practice and only in the exceptional case is it necessary to determine oxygen and carbon monoxide with each analysis made.

Referring back to the furnace reactions on page 3, it will be noted that the best practice is that which gives the lowest percentage of oxygen and free carbon monoxide gas or, in other words, that which gives the highest percentage of carbon dioxide gas. The reaction (1), resulting in complete combustion, theoretically yields about 20 per cent carbon dioxide, but in furnace practice the reaction is never a complete one and as a result a certain percentage of free oxygen or free carbon monoxide may be present. This means that

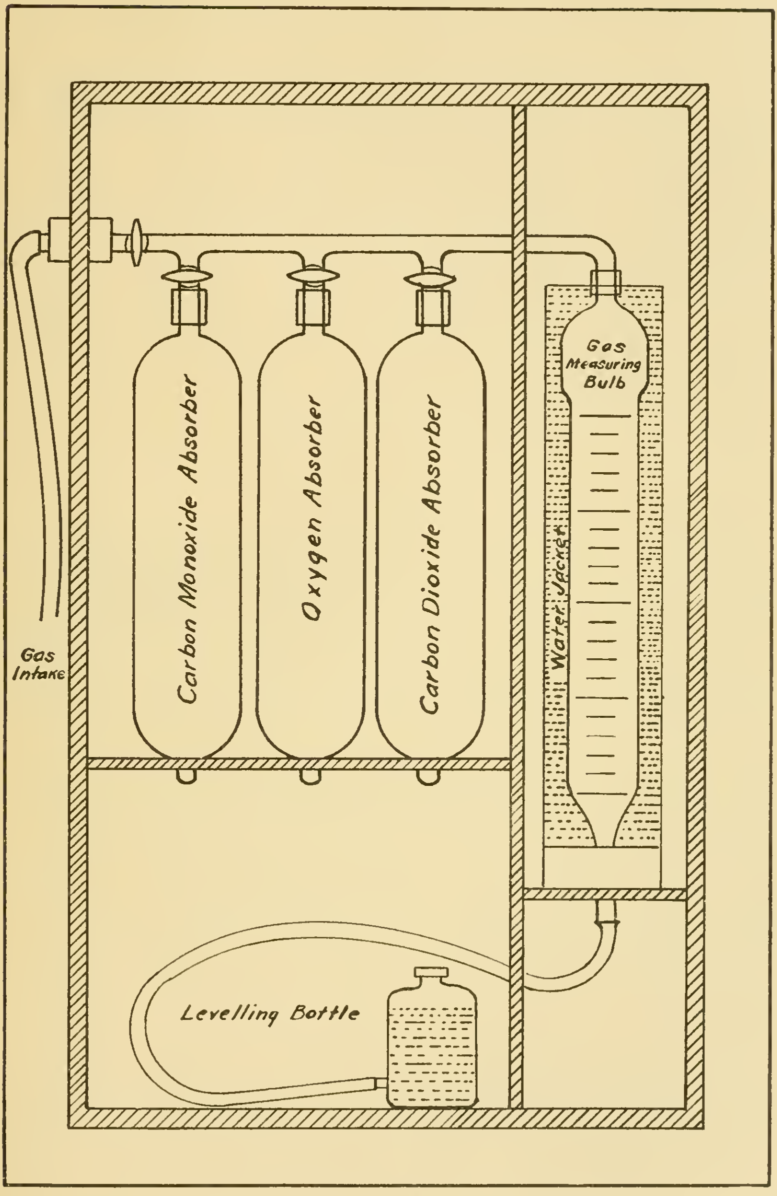

FIG. 2.—Simple Form of Orsat Gas Analyzer.

carbon dioxide never reaches 20 per cent in practice, the best average being around 15 per cent. Leaky furnace settings and other conditions may very materially affect the best practical figure for carbon dioxide, and accordingly that which proves to be the best for one furnace may not be the best for another. Each furnace operation, therefore, becomes to a more or less degree a case unto itself. A number of tests of furnaces in operation have shown an average yield of between 5 and 7 per cent carbon dioxide, which means that as nearly as generalities may be drawn, there is an undue volume of flue gas and a corresponding loss of heat. Satisfactory results, however, are measured in terms of steam produced per pound of fuel burned, so that for a given case the best practice is to secure that percentage of carbon dioxide which will produce the maximum of steam. Right here is to be seen the need of co-ordinating between a carbon dioxide indicator and a steam flow gage.

Air Control

We have observed how the analysis of flue gases is an index of the extent to which proper combustion is effected, but it must be apparent also that these analyses do not give any indication as to the conditions which produced them. For example, a furnace may be operating with a good carbon dioxide yield and steam output when suddenly the flue gas analyzer indicates a falling off of the former and the steam output drops. It is decided that too much air is entering the furnace and the damper is adjusted to cut down the draft, but the steam output continues to fall. Again the damper is adjusted, this time to increase the draft, but still no improvement is observed. The facts in the matter are that one or more of a number of things may have occurred such as the formation of clinkers, holes burned in the baffles, holes in the fuel bed, or an opening in the setting, any one of which may have caused the trouble but which damper manipulations alone could not correct and which are not indicated by the gas analyzer.

There is need, therefore, for an indicator of furnace conditions which is furnished by the draft gage. Its method of operation and the interpretation of its readings, however, require a little explanation.

We are all familiar, in a general way, with chimney drafts. The pull of this draft creates a partial vacuum within the furnace so that a pressure exists there which is less than that outside. To equalize this pressure difference, air enters the furnace and is sucked up through the fuel bed, passes through the combustion chamber and around the boiler heating surfaces and so on out of the stack, but the resistances met with in its flow prevent complete equalization, so that a difference in pressure, or differential pressure, as it is called, always exists and in amounts proportional to the resistances. Any untoward condition, however, taking place within the furnace, such as a hole in the fuel bed, alters the resistance to the flow of air which, in turn, causes the differential pressure to change. In other words, the pressure differential affords a measure of the air feed and an indication of furnace conditions as well. Such is the draft gage, for it is a pressure recording instrument made especially to indicate the pressure difference between the outside and inside of a furnace.

When furnace conditions are right and the percentage of carbon dioxide is such as to give the maximum steam output, a certain amount of resistance exists in the furnace, represented by a certain pressure difference indicated on the draft gage. As long as this condition exists, there is an assurance of the existence of a uniform pressure, but if some change takes place within the furnace which alters the resistances, permitting an increase or decrease in air supply, it is immediately indicated by a change in pressure. In many instances the condition can be corrected in time to prevent any appreciable change in steam output and before its effect is indicated in the quality of the flue gases. In other words, the draft gage intelligently used is the mainstay of an established furnace practice.

Flue Gas Temperature

Experience in chemical control has demonstrated that success is attained in the degree to which each and every operation involved is under observation. Thus, in the case in hand, the objective is the most economic production of heat for the steam output required, and while there is a surety that with the proper co-ordination of flue gas analyses and steam output maintained by a draft gage the objective is being attained, still a further check such as the temperature of the gases as they leave the boiler heating surfaces, will, in a measure, constitute more or less proof, inasmuch as the generally accepted permissible temperature of the gases as they go up the stack is around 500 degrees Fahrenheit. Obviously, therefore, the use of a thermometer or some other temperature recording device will be beneficial. It is conceivable, too, that even though proper combustion is taking place and sufficient heat is produced, a condition may arise whereby the heat so produced is not being absorbed by the boiler heating surfaces or that the latter are deprived of sufficient opportunity to absorb the heat, so that excess heat would pass up the stack. Thus, a temperature recording device may be an indicator both of the heat producing and heat absorbing functions of the furnace.

Limitations

Recording devices whatever their nature do not in themselves provide the requisite control of furnace operations but simply substitute exact data for guess-work to guide the operator. Accordingly, the installation of any system of control will be effective only in proportion as the data are intelligently interpreted and applied.

The case comes to mind of a large central heating plant with a wide-awake chief engineer, cognizant of fuel wastes and means for their elimination, who equipped each one of his mechanically stokered boilers with draft gages, a permanently installed flue gas analyzer and a recording thermometer, and with this apparatus established his standards. His firemen were apparently brought to the point of seeing the advantages to themselves of making use of the equipment and were fully instructed as to the meaning of it all. In spite of this, on several occasions the engineer has come upon a fireman closing a hole in the fuel bed by firing coal through the two-foot cleaning door on the side of the setting, thus allowing volumes more of air to enter the furnace than could possibly enter even through the hole in the fuel bed, and in spite of the warnings, the engineer to-day is not sure but that, when the occasion arises, the firemen will repeat the same operation. In short, the human factor must be considered.

There are two general types of control apparatus, namely, indicating and recording. The former type is of value only as providing a guide to the fireman and is no safeguard against his failings. The recording type, however, in furnishing an uninterrupted register, serves not only as a guide to the fireman but also as a record of efficiencies for the operator.

Costs

The simple form of Orsat gas analyzer, designed along the lines of the sketch shown on page 11, may be purchased for around 40 dollars. It is a portable outfit and properly used, can make a carbon dioxide analysis in about a minute's time. There is also the fixed installation equipped with gas collector ready at any time to make analyses. Another device is in the form of a continuous indicator with or without the further refinement of a permanent record.

A steam flow meter in its simplest form represents an outlay of approximately 175 dollars and a draft gage by itself around 15 dollars. A compound recording device, registering on the same chart and at corresponding moments both flue gas and draft conditions, is to be had as standard equipment. A still more comprehensive equipment indicates the fire-box draft and the steam flow, and registers and records the steam flow, air flow and flue gas temperature all on one chart. This latter order of equipment represents an outlay of approximately 700 dollars.

The very nature of control equipment presupposes some intelligent attention to maintain it for continuous operation. Fresh reagents must periodically replace those being used in an analyzer and again a supply of charts for the recording types of instruments must be had. It is conservatively estimated, however, that a direct recording flue gas analyzer, for example, can be kept in continuous operation at a cost of about 30 dollars annually.

Advantages

Fuel economy is dependent upon two factors, adequacy of installation and boiler room efficiency. Both are variable factors and, as a natural consequence, the data assembled as to furnace practices show an extraordinary range of efficiencies. One operation is getting a yield of from seven to eight pounds of steam for each pound of coal burned, while near by another of exactly the same order is getting but three or four pounds. In the face of these varying efficiencies, no exact statement generally applicable can be made as to the possibility of savings through subjecting an operation to chemical control. Instances are on record of cutting fuel costs as much as 50 per cent, which probably represent the upper limit of advantage to be gained. On the other hand, it is safe to say that no rule of thumb procedure can approximate the exactitude of chemical law within 10 per cent; in other words, a saving of 10 per cent in fuel costs may be counted upon with assurance.

The direct saving in dollars and cents on the fuel bill is not the only line of advantage to be gathered. The furnace room is the energizing force back of the plant operation, whatever its nature, and dependability for meeting the requirements as they arise is the prime requisite. A sudden demand for steam met by opening up a draft so wide as to feed excess air which results in cooling the boiler tubes and actually lowering the steam flow, does more than waste fuel because it impairs efficiencies throughout the plant. Thus, losses perhaps many times over that in fuel may be entailed, all of which would be prevented or even anticipated by furnace control.

Still another aspect of the situation merits consideration among the advantages to be gained. Cost accounting has come to be regarded as a necessary adjunct to effective administration. It has an importance beyond that of any direct cutting of costs in that it affords protection against any unjustifiable developments which might otherwise go unnoticed. Furnace control data, more particularly those afforded by the recording type of instrument, furnish what amounts to a system of cost accounting and have precisely the same advantage as a measure of protection that the more orthodox form offers.

QUALITY OF COAL

There are two general classes of coal used, anthracite and bituminous. Adding the adjectives good and poor, for the majority of users both large and small, this just about sums up the actual discriminatory knowledge of the subject.

The administrative head of a nationally known organization, experiencing difficulty in obtaining anthracite, raised the question of shifting over to bituminous coal, but was met with the reply that the power requirements were of an order that could be met satisfactorily only by anthracite. As the difficulty in securing anthracite increased, he became more persistently inquisitive until, at length, word was passed to him from a subordinate in the power house that the engineer in charge was an "anthracite engineer," and that bituminous coal of proper specification might be made to serve the purpose as well, if not better. The change was finally ordered and has been in effect ever since, with the result that bituminous coal has shown itself preferable in every respect.

The responsible head of a locally prominent plant, approached on the question of fuel economy, professed to regard it as something to which he had given careful consideration in the running of his plant, and stated that all his coal was purchased on a heat unit basis. Questioned further, he disclaimed any particular interest in any of the other characteristics of coal for the reason that heat units were what he wanted and, accordingly, heat units were what he was interested in buying. Examination of his furnace operation revealed around 40 per cent of preventable losses.

Still another executive of an industrial operation, after raising the question as to the relative merits of New River coal versus that bearing a well-known trade name, himself proceeded to answer the question with the statement that in his experience the trade name coal was vastly superior to New River. It happens that the trade name, while originally employed to designate a coal of a certain mine, is no longer applied to the product even from a fixed district and, as a matter of fact, the coal of this name has been coming for the past few years from the New River District.

Instances of this order can be added to more or less indefinitely and serve to show the degree to which what passes for knowledge is actually built up of notion. In times past coal has been so cheap and available that there has been little occasion to give it any particular consideration, which doubtless explains to a considerable degree the lack of genuine discriminatory knowledge of the subject. The system of marketing coal, however, has contributed largely, perhaps even to being the factor generally responsible.

The mining and marketing, more particularly the retail marketing of coal, are two totally distinct industries. The mine operator is utterly out of touch with retail yard operations and vice versa. Moreover there is no immediate connection, the two being separated by an intervening middle interest. The reason for the middle or so-called jobbing interest is to be found, largely at least, in the ever fluctuating price of coal at the mines, and the reason for this, in turn, lies in the vast extent of the bituminous coal lands coupled with the wide variation in producing costs. Given under production, the mine price of coal takes an upward turn and as it mounts, mines hitherto shut down owing to prohibitive mining costs, are able to open up. This process of increasing price and increasing production continues until over production is reached, when a decline in price sets in which forces the little, high cost operators to shut down. This continues in its turn until under production is reached, starting the cycle over again. In the face of this condition at the source, any fixed contract price, whatever the figure, is bound as time passes to reflect to the disadvantage of one party or the other, and each is pretty apt to find the means for avoiding the contract.

The coal retailer generally buys through several jobbers, each of whom handles the product from several mine operations and, as a consequence, the retail yard commonly receives coal, even of a given type, from a number of mines. At best, there is a considerable range that requires separation when we consider the radically distinct types of coal and the various sizes, and when we add the varying products from a number of mines, the range precludes the possibility of having a complete separation even in the best equipped yard.

Disregarding this unreasonable multiplicity of qualities, grades and sizes, the average retail yard is, to say the least, poorly equipped to maintain uniformity in the quality of the coal it distributes. It is hardly more than a railway trestle dump and is commonly located toward the heart of the city where the growth of municipal fixtures has prevented expansion. The general result is a series of trestle dumps, too few to admit of adequate grading of coal and too low to the ground to admit pocket storage and loading, with the net consequence that the coal of a given type, even though coming from various mines, is dumped together on the ground.

Samples of bituminous coal gathered from the yards in almost any city will show an ash content ranging from 2 to 20 per cent; sulphur from less than one-half of 1 per cent to upward of 4 per cent; from high fusible ash to low fusible ash; from 15 per cent volatile matter to 40 per cent; and from almost wholly slack to 70 per cent lump. The group characteristics, volatile matter, ash, sulphur, etc., run more or less uniform for a given mine but vary for different mines even in a given district. Accordingly, the yard procedure just outlined results in the inability to maintain anything like uniform standards of quality. Furthermore the average consumer, in not being educated as to fixed standards, quite naturally lacks adequate discriminatory knowledge of the subject, which, however, has an important bearing on fuel economy.

Thus has come about a vicious circle in which the consuming interests, not having been educated up to require uniform standards, do not demand them, and the marketing interests, having no call for uniform standards, have taken no pains to supply them. This is an unfortunate situation for, as will readily be seen, it stands in the way of subjecting furnace practice to chemical control. One coal requires a thicker fuel bed, another a thinner bed; one requires a larger, and another a smaller combustion space; one requires a weaker and another a stronger draft, and so on. Fortunately there are evidences which point to the dawning of a new era in which standards of service will be developed in keeping with recognized standards of requirement. This will be speeded up or retarded just in proportion as the consumer learns the value of uniform standards.

The principles underlying combustion and the consequent advantages to be gained by chemical control are applicable all the way from the small household furnace to the largest of power installations. There is this general difference, however, that the latter is under continual observation, whereas the former receives but casual attention at intervals during the day and then, at best, of a perfunctory nature. Accordingly, the use of control instruments of the order mentioned for household furnace operations is of no advantage since these instruments are only indicators of conditions and guides to efficient combustion.

Instruments as a guide to chemical control become applicable as attention to furnace operations becomes more or less constant; in other words, as the consumption of coal reaches the stage of tons per day. One plant may feel justified in supplying draft gages only, while another may be able to provide a gas analyzer in addition, but just in proportion as a complete system of control is instituted there is the consequent assurance of securing definite economics. Irrespective of the actual savings to be effected, the application of chemical control by all consuming interests must bring about that discriminatory knowledge of the general subject which is now largely lacking. Once this is attained and standard practices are established, the consumer will be in a position to demand and receive uniformity and service of the marketing interests.