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Alberta Coals and Automatic Domestic Stokers

BY

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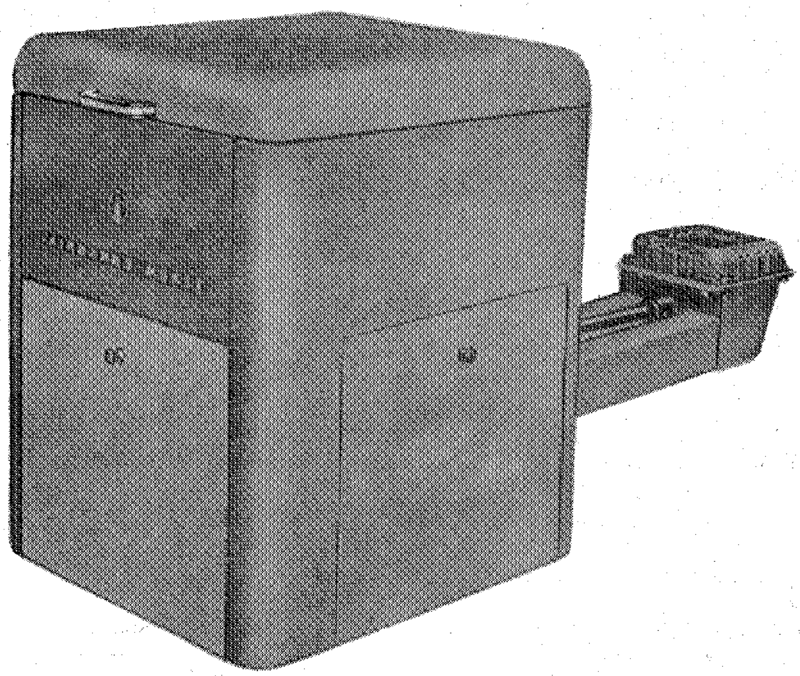

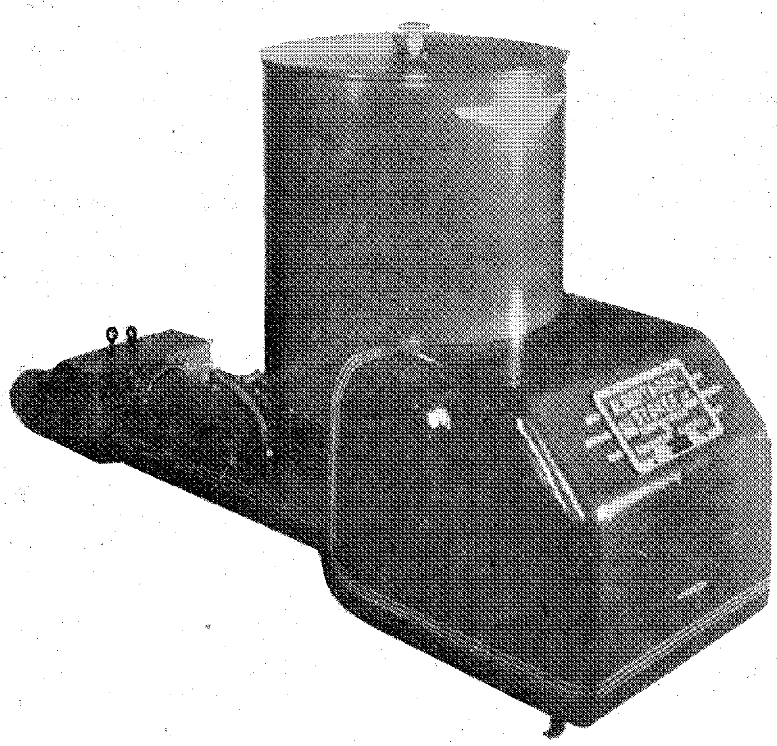

FRONTISPIECE

A Fairbanks-Morse Underfeed Stoker—upper

An Alberta Coal Stoker—Coutts Machinery Co. Ltd.—lower

Alberta Coals and Automatic Domestic Stokers

INTRODUCTION

Laboratory investigation and questionnaire as sources of information.—In 1942 the Research Counciil of Alberta decided to carry out an investigation on the suitability of Alberta coals for use in automatic domestic stokers; and funds for this work were provided by the Legislature in 1943, '44 and '45.

A building and duplex chimney were erected on the campus of the University of Alberta, and two hot-air house heating furnaces were purchased and installed. One furnace was equipped with an underfeed stoker and the other with an overfeed stoker.

Considerable preliminary work was done to establish the best methods for operation and control, and a standard test procedure was evolved. Subsequently twenty-three coals were tested, eighteen in the underfeed and eighteen in the overfeed stokers. Details of the tests are given later. It must be stressed that the investigation was designed to ascertain Alberta coals suitable for use in each type of stoker; no attempts were made to test the efficiency of either stoker, and no attempts were made to change the stokers or adapt them in any way for use with coals for which they were not primarily suited.

Valuable information was gained as to the characteristics desirable for stoker use, and as to the availability of such coals in Alberta. However, it gradually became clear that although it was possible to establish certain broad generalities it was not possible to classify all coals as definitely suitable or unsuitable for either stoker. A coal found entirely suitable, by test, for use in one stoker was found to have given serious trouble to a householder using it in a similar stoker. On the contrary, a coal found satisfactory by a householder might give trouble in the tests.

The size, fire bed temperature, and other conditions of the fire in a particular stoker, are influenced not only by the coal fired but also by the relation of the size of stoker to size of furnace, and the relation of both to the heat requirements of the house as well as by the type of furnace. A coal may give satisfaction under the fire conditions of one installation and be quite unsatisfactory in another. One installation may work best with one size of coal and another require a different size. Moreover, successive deliveries of coal from a certain mine may vary somewhat in ash content and in clinkering characteristics.

It was therefore decided that, before proceeding to write this report, it would be well to send out a questionnaire to users of automatic stokers in order to learn what coals they burned and their experiences with these coals. The conclusions and opinions expressed in this report are based on the laboratory investigation and on the replies to the questionnaire.

Secondary investigations, clinker and smoke formation.—Supplementary laboratory investigations included studies of the clinker producing and smoke producing character of the coals. In the first, chemical analyses of the ash were made, determinations of fusion temperatures, determinations of clinker density, and studies made of the possibilities of modifying clinker formation by coal washing, by the addition of chemicals to the coal, or by blending with other coals. In the second investigation a laboratory method was evolved for determining a numerical evaluation of the smoke forming tendency of the coal and more than fifty coals were tested. These investigations are described later.

The stoker, and competition between coal, oil and gas.—The automatic domestic stoker is a reply of the coal industry to the competition of natural gas and oil as fuels for domestic heating. Coal is in general notably cheaper than either gas or oil; but gas and oil are cleaner and more convenient and many householders are willing to pay the higher price for the sake of convenience. Gas in particular is brought to the house in a pipe and can be fed to the burner simply by turning on a tap. The heating system also can be readily subjected to thermostatic control, whereby the heat supplied to the house is restricted to the heat required to maintain the desired house temperature.

The hand-fired, coal furnace usually burns lump coal, and this coal may have to be shovelled into the furnace twice or three times a day. The grates may have to be shaken each time of firing, and the ashes removed from the ash pit two or more times a week. The drafts in such a furnace can be thermostatically controlled, but this is seldom done, and the reaction is not quick as a large, hot fire only cools slowly after the draft is cut off.

The automatic domestic stoker burns small coal, usually sold at a lower price than lump coal, the hopper seldom needs to be charged more than once a day and there are no grates which need to be shaken, but ash removal does require attention as will be described later. Stokers normally are thermostatically controlled and the coal in the fire pot is small in amount so that stokers react reasonably quickly to changed conditions. In some installations the coal is fed directly from the coal bin to the stoker fire, thus removing the need for hopper filling; and in some exceptional installations the ashes are mechanically removed.

It cannot be claimed that the automatic domestic stoker will give as much satisfaction and as little trouble as will a gas or oil fired furnace; but the fuel economy may be considerable. There are many well satisfied users of the stoker and the number of installations is steadily increasing. The difficulties and the disadvantages of the stoker will be discussed in a later section; but it can be stated here that many of the difficulties, in the opinion of the writers, are due to the fact that in general stokers have been made to be inserted into existing furnaces, where, in short, the installation is a makeshift. A carefully designed stoker-furnace unit would obviate many of the present difficulties. Serious trouble and damage to the prestige of stokers have been caused by the installation of stokers in unsuitable, or even in leaky, furnaces by irresponsible parties.

The automatic domestic stoker is essentially a compromise between the simple and cheap hand-fired coal furnace with its reasonably cheap coal fuel but troublesome operation on the one hand,

and the more expensive fuel cost but the essential simplicity and ready control of the gas or oil installations on the other hand. Stokers are frequently inserted into existing installations of coal fired furnaces; but also are installed in new residences. It is for the latter case that an integral stoker-furnace unit should be available. The final choice of installation in any case must frequently depend on the capital available, the price the householder is willing to pay to save himself from work or inconvenience and the availability and relative prices of suitable coal, gas and oil fuels at the location in question.

The operation of a stoker in house heating.—In stoker installations there is a hopper into which a suitable size of coal, normally inside the extreme limits of ¼″ and 1¾″, is charged. The coal is mechanically withdrawn from the base of the hopper, by means of an auger, or worm drive, which carries it along an auger tube into a retort where it is burned. The retort is installed inside the house heating furnace, which furnace may be hot air, hot water or steam. The retort and its connections are frequently inserted through the ash door of the furnace, but for convenience may be inserted through side or back of the furnace.

The auger is driven by means of a small motor of ¼ H.P. or larger. The same motor also drives a blower fan which forces air along an air duct, beside the auger tube, and thus sends the air needed for the combustion of the coal into the air box of the retort and thence through the tuyeres, or air ports, into the burning coal in the retort. The auger is connected to the motor through pulleys and belts and a reducing gear. Adjustment of the rate of drive, to suit the conditions of the installation and the selected coal, can be made by changing the size of pulleys used. The blower fan is commonly attached directly to the shaft of the motor, and the adjustment of air supply is made by means of a damper. When once the coal feed and air supply are correctly adjusted further change should not be required.

The thermostatic control starts and stops the motor, so that coal feed and air blast are either both on or both off. However, there is a slight current of air through the retort, due to chimney draft, even when the motor is not running so that a slow rate of combustion may be maintained in the retort for a considerable time, and the fire thus kept alight ready for action when next the thermostat restarts the motor. But in order to avoid all danger of the fire going out between firing periods, in mild weather where the heat requirement may be very small, it is customary to supply a hold fire attachment whereby, regardless of the heat requirements, the motor is periodically run for a short time, customarily two to five minutes every hour.

The above description, it must be understood, only covers the actual stoker unit. The furnace must be provided with means for absorbing the heat from the burning fuel and distributing it through the house, as well as a flue pipe and chimney, etc. Since the air for combustiton is supplied under slight pressure, instead of being drawn in by the chimney draft as in a hand-fired furnace, it is essential that the furnace should be gas tight, and the chimney ample to remove all products of combustion; otherwise flue gas and dust may escape into the house.

Where an ash pit is provided under the furnace it is also essential that this be effectively sealed off from the warm air circuit, as otherwise flue gas and dust may escape into the house. This necessity is sometimes overlooked by inexperienced or careless workmen.

In the hand-fired coal furnace the fire is kept burning fairly steadily, with only occasional changes of draft to adjust the fire to climatic conditions. In the thermostatically controlled, automatic, domestic stoker the fire (coal feed and air feed) are either fully on or off; but in cold weather the on periods may be long and the off periods short whilst the reverse will hold in mild weather. The fire, during the on periods, is usually more intense than at any time with a hand-fired furnace, and this accounts for the tendency to give off fly-ash, and the greater tendency to form clinkers. With the stoker the supply of heat to the house will also rise and fall as the motor is turned on and off.

Underfeed and overfeed stokers.—There are many meritorious makes of automatic domestic stokers, but in general these belong to one of two types known respectively as underfeed and overfeed stokers. The underfeed stoker will give smokeless combustion with a wide range of coals; the overfeed stoker is specifically designed for the free-burning, lower rank coals—the type of coals commonly known as "domestic coals" in Alberta, coals which burn freely without smoke.

In the underfeed stoker the auger tube carries coal to the base of the retort or fire-pot, as shown in Fig. 1, whence it is slowly pushed to the top of the retort by the following coal, where it meets air entering from the ports and is thus burned. The coal gets hotter and hotter as it rises up through the retort, but the volatile matter, which might cause smoke formation, that is given off in the retort has to pass up through the hot fire zone, and thus is completely burned. The ash left when the coal is burned is carried to the very top of the fire and it largely rolls or falls from the top of the mound or cone onto the surrounding zone or ring. In most patterns of underfeed stoker there is no automatic removal of ash; it is therefore desirable to burn a clinkering coal, as the clinkered ash can then readily be removed from time to time through the fire door of the furnace by means of tongs provided for the purpose. This is not entirely satisfactory as some coals may not give a firm enough clinker for easy removal, whilst other coals may form such a dense, hard clinker that it blocks the air current, and interferes with regular combustion. On the other hand the removal of clinker with tongs is easy and causes a minimum of dust. It is suggested that a well designed underfeed stoker-furnace unit would provide automatic removal of both clinker and ash, and thus allow for satisfactory operation with a wider choice of coals.

In the overfeed stoker, as shown in Fig. 2, the auger feeds the coal to the rear end of a shovel shaped retort, partially covered at the rear end, and with a grid or grate in the floor of the retort through which air is admitted from the air box or hollow base of the retort.

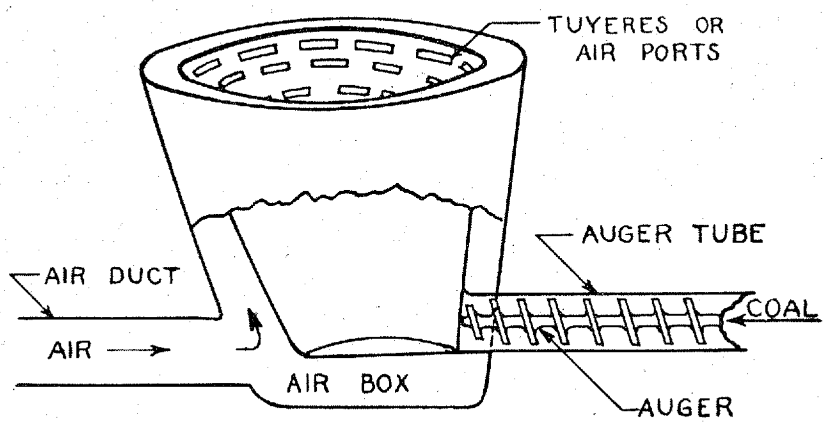

Fig. 1—Sketch of an Underfeed Type of Retort

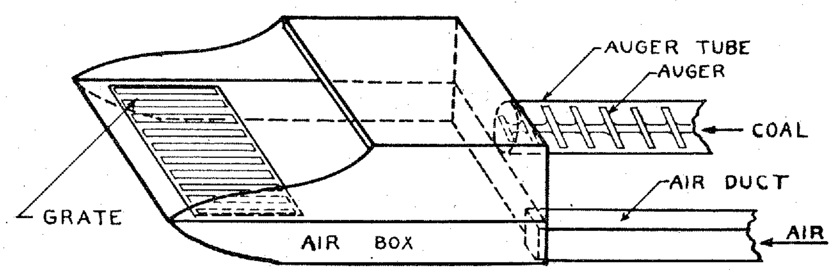

Fig. 2—Sketch of an Overfeed Type of Retort

The coal, entering at the rear, is gradually pushed forward over the grate where there is active combustion. The ashes and clinker, left after combustion, are forced off the open end of the retort, and fall into a container, frequently placed in an ash pit under the furnace.

It can be realized that this stoker has no specific feature for smokeless combustion, but it is designed for use with smokeless or low-smoke coals. The coal must be sufficiently free burning to be completely burned during its passage from end to end of the retort, otherwise unburned coal will fall into the ash pit and be lost. With this stoker the coal need not clinker; trouble may be caused, however, with coals which form a dense, hard clinker that blocks the entry of air to the fire. Such a clinker may even bridge the space from the retort to the wall of the furnace, instead of falling into the ash pit, and thus block the forward movement of coal along the retort. The use of the overfeed stoker is mainly confined to the West, where free burning coal is available at a comparatively low price. The automatic removal of the ash into a container in the ash pit is one of its notable advantages.

With both types of stokers the rates of feed of coal and air can be so adjusted that efficient combustion is assured, with little loss of fuel with the ashes or as unburned gas with the flue gases. A slight loss of unburned coal with fly ash may be unavoidable. The efficiency of an automatic domestic stoker furnace should be distinctly higher than that of a hand-fired furnace, and the use of a cheaper coal be possible.

Some houses are heated with a blower installation. The air for combustion is forced into the ash pit of an ordinary furnace—with the ash door, etc., cemented to prevent leaks—but with the coal hand fired and burned on a standard grate. Such installations will not be discussed; but since the ashes are preferably removed as clinkers by means of tongs, the same coal specifications, with regard to the clinkering character of the ash, are applicable as for coals for the underfeed stoker.

Acknowledgements.—The overfeed stoker used for the tests was an Alberta Coal Stoker loaned without cost by the Coutts Machinery Co., Ltd., Edmonton. Mr. T. H. Coutts gave valuable advice as to its installation, operation, and adjustment to different types of coal. The underfeed stoker used was a Victory model, Fairbanks-Morse stoker, supplied at cost price by the Canadian Fairbanks-Morse Co., Ltd. Mr. P. McGarvie, local manager of the Edmonton branch, similarly gave valuable advice and assistance. Grateful thanks are given to all concerned. Illustrations of these makes of stokers, but not of the actual stokers employed, are shown in the frontspiece.

The control instruments and accessories were those of the Research Council of Alberta.

The installation, operation and tests were done by the junior author, with analytical and unskilled assistance by regular members of the staff of the Council, and the work was carried out and reported as part of the requirements for the M.Sc. degree of the University of Alberta, a degree awarded in 1945. The work was planned and carried out under the guidance of the senior author.

DESIRABLE AND UNDESIRABLE PROPERTIES OF STOKER COALS

The essentials for a coal for either an underfeed or overfeed stoker are combustion characteristics permitting the ready generation of the required heat in cold weather, and the maintenance of some fire in mild weather, without undue smoke or trouble with clinker or ash. The coal should be clean, free from dust, and suitably sized to suit the stoker in question.

Combustion Characteristics of Coal.—Both high and low rank coals can be burned in automatic stokers; but the former have higher calorific values than the latter*. The heat value is of minor importance when the coal is burned close to the mine, but becomes of greater and greater importance with the distance to which the coal must be shipped, since the lower the heat value, the greater the weight of coal shipped, and the greater the freight paid, for a given heat requirement at point of destination.

The underfeed stoker has a combustion bed of considerable thickness and the coal may remain therein for a long period. This stoker therefore can burn both low rank coal and high rank coal, if the latter is not too strongly coking. The overfeed stoker, designed

*For analyses see "Coals of Alberta," Report 35, Research Council of Alberta.

for burning low rank coals only, has a shallow fire bed across which the coal moves in a comparatively short time, a procedure, as already stated, only suited to free burning coals.

Strongly coking coals cannot be efficiently burned in the ordinary underfeed stoker, that is, one without a mechanical mixer and/or special tuyeres. A coking coal when strongly heated, as in passage through a combustion zone, loses volatile matter and becomes plastic. The evolution of gases from the plastic mass causes it to become cellular, and further heat converts it to the hard, low volatile, cellular mass known as coke. Coke only burns at high temperatures, and burns less readily than does the original coal, so that it may form a column or "tree" that rises unburned through the top of the fire. Such a formation is termed a "coke tree" and it may rise two or three feet above the fire before it topples over. Much of it then may fall outside of the active fire zone and remain unburned. Other things being equal, a thick fire bed is less likely to give coke tree trouble than is a thin fire bed.

The ability of a coal to stay alight in mild weather when the stoker operates only on the automatic timer is a significant characteristic. The property is related to the ignitability of the coal and depends on its rank. However, considerable leeway is provided by most varieties of the automatic timer superimposed on the thermostat since they are adjustable and can usually be set to give a satisfactory stay alight fire for any coal.

Smoke issuing from a chimney is lost heat value in addition to being a nuisance to the neighborhood. Smoky combustion also causes the radiation surfaces of the furnace and flue pipes to be covered with an insulating layer of soot, thus occasioning a further and more serious loss of heat.

In the underfeed stoker, as already stated, the underfeed principle, whereby the raw coal is fed to the bottom of the combustion zone, and the smoke forming constituents pass up through and get burned in the hot fire, enables smoky coals to be burned smokelessly. The formation of coke trees, interfering with smooth combustion, however, may result in smoky combustion.

Ash Content and Ash Clinkering Character of Coal.—A low ash coal is desirable for any stoker, but with the ordinary underfeed stoker both a low ash, and a suitably clinkering ash, are particularly desired. A high ash coal results in the rapid accumulation of clinker and ash in the furnace. This naturally necessitates more frequent removal; but even so the smooth and efficient operation is interrupted. A coal with more than one pound of ash per therm (100,000 B.t.u.), i.e., 10% ash for a 10,000 B.t.u. coal, is inadvisable. This method of rating the ash relative to the caloric value of the coal seems a much fairer criterion than is the straight percent of ash.

A satisfactory clinker for the underfeed stoker is one which is strong enough to allow removal with tongs, but porous enough to permit the passage of air for combustion to the unburned coal above the clinker ring. The word "porous" is ambiguous; clinkers in which there are passages through which air can pass easily, and clinkers with enclosed air spaces might both be described as porous, but only the former would permit the passage of air to the fire bed.

A clinker with visible air passages will be referred to as porous, and one with enclosed air spaces as cellular. No method was found for determining the porosity of a clinker other than by visual observation. The percentage air space was calculated for a number of clinkers, from the determined true and apparent specific gravities; but these values were not found to be significant.

Several underfeed stokers are described later for which a clinkering ash is not desired.

Ash and clinker specifications for the overfeed stoker are notably less stringent. A low ash coal is desirable but not required. A non-clinkering ash is preferred, but clinkering is not detrimental unless the ash is so fusible that a hard clinker is formed which interferes with the supply of air through the grates. In extreme cases a "clinker bridge" may be formed bridging across the fire pot of the furnace and lodging against the opposite wall. This blocks off the air supply causing much of the fresh coal to drop into the ash pit before being more than partially burned.

Dust created in shovelling coal into the stoker hopper may be very obnoxious to the householder. This dust, worse from some coals than from others, can be reduced or eliminated by screening, oiling, or chemical treatment of coal intended for sale as stoker fuel. Oiling a coal, besides diminishing dust trouble, increases the calorific value.

Fly Ash Formation.—When a coal is burned under forced draft, as in a stoker, small particles of completely or partially burned coal are picked up by the blast and carried forward to be dropped in the furnace, flue pipe or chimney, or discharged from the chimney. These particles are termed fly ash. Fly ash, besides representing the loss of a small amount of combustible material, insulates radiation space occasioning loss in efficiency of heat transfer. While all coals produce fly ash, a coal to be well suited to stoker use, should not produce an excessive amount; even a normal amount should be removed once each heating season. Ordinarily a high ash coal produces more fly ash than does a low ash coal.

Coal Size.—It is important that the coal should be the correct size for the stoker. The coal should not be so large that the larger pieces are excessively fractured in the auger tube. Fines, whether originally present in the coal, or produced by fracturing, will cause fly ash trouble. The size of coal suited to any particular size of stoker is largely dependent upon the dimensions of the auger and auger tube, but coal that passes a ¼″ and coal retained on a 1¾″ round hole screen are seldom employed. A common sizing is ¼″ to 1¼″. Wet coal, particularly when poorly sized, may cause trouble owing to bridging in the hopper.

MECHANICAL FEATURES WHICH MAY BE INCORPORATED IN STOKER INSTALLATIONS

All stoker manufacturers claim special merit for certain mechanical features incorporated in their stokers. A number of these, and of supplementary controls, etc., have been collected from stoker literature and are listed below. Some of these items are standard equipment whilst others are luxury items. Some are made by the stoker manufacturers, specifically for their own stokers, whilst others, particularly controls and protective devices, are frequently made by specialty manufacturers and can be installed with any stoker.

Controls and Protective Devices.—A thermostatic control and a "hold-fire" device, as already discussed, are normal equipment for stokers. Thermostats range from the simple, manually set model to the clock regulated models which can automatically lower the temperature setting at night and raise it again in the morning. Stokers also are generally supplied with air temperature, water temperature, or steam pressure controls to prevent overheating in hot air, hot water or steam furnaces respectively. These latter controls are superimposed on the thermostatic control and prevent danger if, for example, there were an open house door in midwinter that would otherwise cause the thermostat to keep the stoker on too long for safety.

A protective device put on many stokers is a shear pin which breaks, and thus avoids more serious damage, when a foreign body in the coal prevents the rotation of the auger; this shear pin can be replaced readily after the obstruction is cleared. Where stokers are installed in greenhouses, etc., it can be arranged that breaking of the shear pin is accompanied by flashing a light or ringing a bell as a warning to the operator. A clean-out plate is often put on stokers at the junction of the hopper and auger tube to facilitate the removal of such an obstruction. A mechanical overload release may be installed in place of a shear pin.

Damage to the electric motor, when abnormal conditions might otherwise cause a burned out motor, are best avoided by means of an overload thermal cut-off switch; this is far better than the ordinary electric fuse. Motors are often rubber mounted to prevent noise during operation.

Back drafts of smoke from the retort to the hopper can be prevented by a flexible tube from the air duct to the auger tube, providing a slight air current in the forward direction. Stokers may be equipped with rubber sealed hopper lids to prevent any smoke reaching the hopper from issuing into the house.

Adjustment of Air Blast.—In the underfeed stoker special allowance may be advisable for varying fire bed depths, and for this type of stoker manufacturers provide devices for a compensating draft control in the air duct. These devices, whatever their trade names, have two objects in common—to supply more air to a thick fuel bed and less air to a thin fuel bed, and to prevent more than a minimum amount of air reaching the retort through the air duct during the off periods of the stokers.

Retort Design.—Manufacturers' claims for the underfeed stoker retort mainly refer to special designs for tuyeres. Various types have been designed to prevent small pieces of coal or ash from falling through the tuyeres into the air box. but a blow-out attachment and clean-out tube are usually provided so that the air box can be cleaned if any does fall through.

One stoker with a modified underfeed retort, having a conical grate with large tuyeres, has been advertised as especially meritorious for low rank coals because it gives a thin fuel bed with a low draft of air through the fuel, and thus burns the coal to a loose ash with few clinkers. The ash in this stoker drops into an ash pit below the furnace through holes in the two sections of the iron hearth. These holes are normally closed, but can be opened by using a poker to slide the top section around on the bottom section until the holes coincide.

One manufacturer makes an underfeed stoker with a cylindrical grate mechanically rotated about a horizontal axis. The coal is carried up one side of the cylinder and the ash left from the combustion of this coal is dropped from the other side into the ash pit by the rotation of the grate.

Some manufacturers have modified the retort of the underfeed stoker to enable it to burn strongly coking coals by incorporating a stirring device which moves through the fuel bed, thus breaking up the coke trees; and by suitably locating the tuyeres to allow coke tree formations to be burned.

Only one special design for the overfeed retort has been noted. This is a heavy iron hood which is fastened above the open end of the ordinary overfeed retort; its purpose is to force the volatiles driven off from the coal in the enclosed end of the retort into the hot flame zone above the fire on the grate area.

Coal Feeding and Ash Removal.—A number of manufacturers make a domestic stoker in which the coal auger is prolonged to feed coal directly from the base of the coal bin to the retort, and thus obviate the hopper, and the necessity of shovelling coal from the bin to the hopper. Also on the market are stokers with an attachment for mechanically removing ash from the ash pit or from the retort area in the furnace. Ash is removed from the ash pit of an overfeed furnace by an auger. With the underfeed stoker an ash paddle may rotate around the retort, collecting the ash and depositing it in an auger tube. In both cases the ash is pushed up the auger tube and dropped into containers which may be outside the building.

TESTS MADE TO ESTABLISH SUITABILITY OF COALS FOR STOKERS

Tests were made with the separate coals in either an underfeed stoker or an overfeed stoker, or in both. These stokers, and the warm air furnaces in which they were installed, are described in Appendices 1 and 2. The special test equipment employed is described in Appendix 3.

When commencing to test a coal in either stoker a preliminary run was made to establish the optimum conditions. The coal feed was first adjusted to give, as closely as possible, a standard output of heat per hour of operation. The standard was set in relation to the rating of the stoker. In this way a slower feed was used with a high heat value coal and a faster feed with a low heat value. Next the air supply was adjusted to give the best possible combustion; this included consideration of the maintenance of a constant fuel level in the underfeed stoker, the absence of excessive combustible in the refuse from the overfeed stoker, a high percentage of carbon dioxide in the flue gases, and, as a necessarily secondary consideration, a low production of fly ash.

Three standardized tests were carried out with each coal tested, in each stoker. These tests were normally of 24 hours duration, but were sometimes cut down when everything was satisfactory, or lengthened when efforts were being made to overcome difficulties. The first test, designed to simulate extreme cold weather conditions, consisted of a controlled periodicity wherein the stoker motor, driving the coal feed and air blast, was alternately on for 15 minutes and off for 15 minutes. In the second test, designed to simulate medium winter weather, a periodicity of 10 minutes on and 30 minutes off was employed. In the third, or hold fire test, designed to simulate mild weather, a periodicity of 2 minutes on and 58 minutes off, or of 4 minutes on and 56 minutes off, was employed. During the first two tests cold air was forced through the furnace casing by means of a fan to absorb the heat generated. Natural draft was ample for this in the third test.

It was found difficult to obtain reliable information as to usual periodicities of domestic installations under different climatic conditions. The choice of the above periodicities was supported by records obtained from stokers operated in two Edmonton houses; the records showed, however, that the periodicities varied widely due to factors other than that of the outside temperature.

The records kept during a test varied somewhat with the stoker employed and with the periodicity, but in general included: feed and air blast setting, duration of test, weight of coal charged and of ash and clinker removed, weight of fly ash collected, frequency of cleaning underfeed stoker fire, visual observations of the fire bed and of the discharge from the smoke stack, and charts of the warm air temperature and flue temperature. Other records kept included occasional determinations of combustion bed temperature (for the 15 minutes on 15 minutes off runs only) and changes of the temperature sensitive paint numerals (for the hold fire rate only).

Full proximate, ultimate and calorific analyses and ash fusion tests were made for each coal. Chemical analyses were made of the ash from each coal. Determinations of true and apparent specific gravities were made on samples of clinkers from both the underfeed and overfeed stokers.

Supplementary tests, described later, were made with some high heat value coals (suitable for shipping to distant markets) with a view to changing their clinkering properties to conform to the requirements of the ordinary underfeed stoker. These included stoker tests with blended coals and with chemically treated coals. A few stoker tests were also made to study the possibility of overcoming coking difficulty by use of blends of coking coals with noncoking coals.

The above records of tests made were used to evaluate the suitability of a coal for each type of stoker; but, as discussed in the Introduction to this report, it is realized that the results of these tests are guides to, but not final criteria of the suitability of any coal. Moreover, the test coal from any mine was not necessarily up to the standard the operator would produce to meet a definite market for stoker coal; for this reason no analyses of the coals tested are included in this report, and any ash analyses or other specific data given are not identified as to the source of the sample. The operators from whom coals were obtained, however, have been supplied with the analyses, ash fusion test, etc., of their own coals.

The most important criterion for any stoker fuel must be its ability to meet the heating requirements of the house, in the installation provided, in a regular manner, with the minimum of trouble. In the tests made the most reliable guide was provided by the charts of the recording thermometers installed in the warm air jacket and flue pipe respectively. A coal burning regularly, gave an oscillating curve which however showed little change in the maximum temperatures of the on periods, or the minimum temperature of the off periods, so long as the fire was continued undisturbed. Fig. 3 shows first a pair of curves for such a coal. It also shows a corresponding pair of curves for a coal which gave interruptions due to excessive clinkering. With the latter it may be noted that the rate of combustion, as shown by the temperatures produced, diminished as the test progressed. In each case the period shown is for the 9th to the 20th hour of the test, inclusive. A coal which formed coke trees showed erratic rather than diminishing temperatures. With an underfeed stoker a coal with excessive ash content, or an operation in which the refuse was allowed to accumulate unduly, showed erratic temperatures each time the clinker was removed. The information given by the charts was supplemented by the visual observations and incidental troubles recorded.

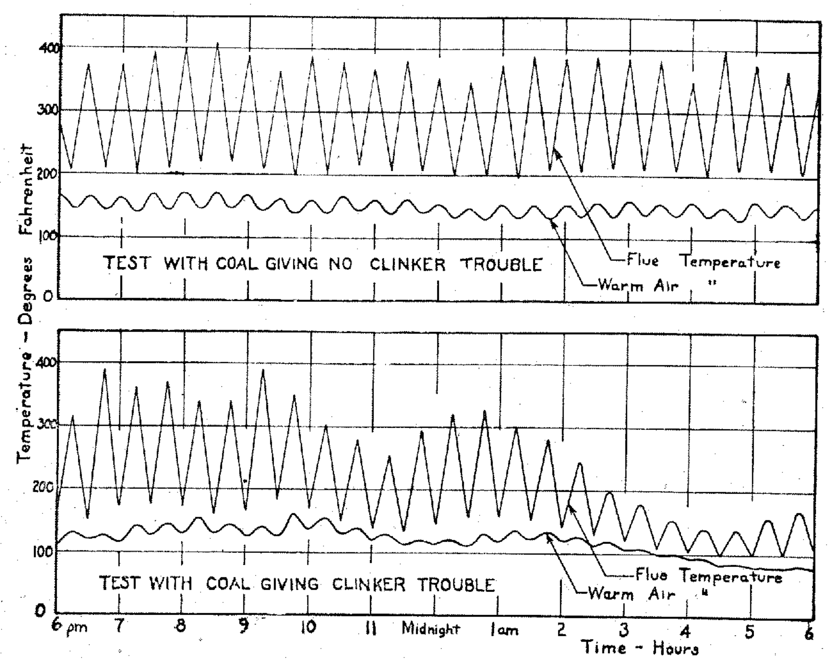

Fig. 3.—Contrast of flue and warm air temperature charts in tests without and with clinker trouble in overfeed stoker; 15′ on and 15′ off periodicity

Regularity of combustion of a coal was judged by its behavior in the extreme cold weather test, as no coal that passed this test failed in the medium winter weather test. The results of the hold fire tests were significant as indicating the required setting for a hold fire timer. Some coals showed a tendency to burn back along the auger tube during the prolonged off periods of a hold fire test. This burning back was shown by the change of colour of one or more of the numbers, 1 to 10, painted on the auger tube with temperature sensitive paint; but this was not found serious with any coal tested. If a coal were to give trouble in this way the condition could be met by a suitable adjustment of the hold fire timer.

An important consideration for a stoker fuel must be the heat value and ash content of the coal. As already stated a low heat value coal may be excellent in the home market, but quite undesirable for shipping to distant markets; but in any market the consumer will, where other qualifications are met, generally purchase the coal which gives him the most heat units for his dollar. A high ash coal always involves trouble with ash removal and disposal, but is particularly undesirable in the ordinary underfeed stoker where the refuse interferes with regular combustion and necessitates frequent cleaning of the fire.

Failure to operate satisfactorily, with the coals tested, was most frequently due to clinkering characteristics of the ash. Some coals formed a dense, hard clinker which interrupted regular combustion in the stoker. This was shown in the temperature records. Other coals did not form a clinker removable with tongs as required for the underfeed stoker used. This was shown by the rising of the fire bed level owing to the gradual accumulation of refuse. Clinker formation and control are discussed in Appendix 4.

Probability of trouble from fly ash was indicated by the weight caught in the trap provided in the flue pipe from each stoker. Smokiness or otherwise of combustion was judged by observations of the discharge from the smoke stack, particularly at the beginning of the on and off periods. A test was devised to evaluate the relative smoke forming character of the coals studied. This is described later in Appendix 5. Dustiness of the coal was judged by inspection.

Other tests and analyses, even though not used directly for evaluation of the fuel, were used throughout the investigation in the attempt to correlate analytical and other data with the combustion characteristics of the fuel.

QUESTIONNAIRE ON COAL STOKERS

For reasons fully explained in the Introduction a questionnaire was sent out to users of automatic domestic stokers in Alberta, and to a few users in British Columbia and Saskatchewan. Over two hundred of the questionnaires were sent direct to the users, where their names and addresses were available, but four hundred more were sent for distribution to 68 individuals and firms who, being engaged in the plumbing, heating and ventilating business, might be expected to have customers operating domestic stokers. Only eighty replies have been received to date of writing (August, 1945). The few replies received from many parts of the Province make it certain that complete returns would have shown many more Alberta coals being burned with satisfactory results in domestic stokers. Some of the replies received were from hospitals, schools, garages, and stores, and in a number of these cases the replies covered the use of more than one stoker.

The questions and summary of replies received, are given below.

(1) Name of stoker and type (underfeed or overfeed) . . . The replies covered six varieties of underfeed stoker, 64 stokers in all, and two varieties of overfeed stoker, 27 in all.

(2) Name or source of coal or coals used in recent years. . . Coals from thirteen areas were listed by underfeed stoker users, and from eight areas by overfeed stoker users.

(3) Approximate number of tons burned last winter. . . The aggregate tonnage covered by the replies exceeded 3,300 tons.

(4) Did you find the above mentioned coals completely satisfactory? If not, how did they cause trouble? . . Some replies dealt with several coals; some coals were mentioned repeatedly and others only once, so the replies are difficult to summarize. For coals burned in underfeed stokers, 47 unqualified approvals were given, whilst 37 cited disabilities. The most frequent criticisms were clinker trouble and excessive ash. Clinker trouble varied from failure to form a removable clinker to the formation of too hard or too much clinker. For coals burned in overfeed stokers 24 unqualified approvals were given in contrast with 10 cited disabilities; the latter were almost all clinker trouble and excessive ash.

(5) If above trouble due to excessive clinkering, may this have been due to a need to force the furnace? . . This question, which was not answered, was intended to reveal cases where the stoker or furnace was too small for the heating needs of the house.

(6) Is your stoker thermostatically controlled? . . Only one stoker was reported as not so controlled, and this was one out of five stokers in the same building.

(7) How are the ashes and clinker removed from the furnace? (by tongs, from a bucket or pan in an ash pit, or by other means). . . In replies re underfeed stokers, only five referred to removal of ash from an ash pit, and three of these were for large installations; the others used tongs. All replies re overfeed stokers gave removal from ash pit by bucket, pan or shovel.

(8) Have you had trouble from coal or other substance jamming in the hopper or auger tube? If so, indicate frequency of trouble. . . One reply said no trouble in eight years. This was unusual, however, as over half the replies referred to troubles ranging downwards from four times in a year. The most common trouble was due to mine spikes and bolts in the coal; but wood chips, stones, wet dust, etc., were also mentioned. A little care whilst filling the hopper, or the use of a screen across the top of the hopper, was said to prevent most trouble.

(9) Do you have trouble from dust? . . 38 reported no trouble, 29 slight trouble, whilst others reported dust from delivery of dirty coal, when filling hopper or emptying ashes, or due to badly fitting furnace doors.

(10) How often do you remove fly ash from furnace or pipes? . . The replies varied through a wide range; but twice a season appeared to represent normal procedure.

(11) (For an overfeed stoker.) Have you had trouble from the formation of a "clinker bridge"? If so, indicate frequency. . . Twelve reported no trouble at all, and others only rare trouble. Three had trouble in extremely cold weather and one when stoker was forced. The possibility that the trouble in these cases was due to an undersized stoker for the house was not discussed. None reported consistent trouble.

(12) (For an underfeed stoker.) Does the coal used clinker sufficiently for removal with tongs, or do you frequently have to remove loose ash with a shovel? . . Of those using tongs to remove clinkers half reported having to supplement this, occasionally or frequently, by removal of loose ashes with a shovel.

Have you had trouble with any coal due to a dense clinker interfering with regular combustion? . . 44 replies reported no such trouble. Some said trouble was prevented by giving a little attention to the furnace. Three reported trouble in extremely cold weather or when the furnace was forced. Some found trouble only with occasional deliveries of coal.

(13) Comment on your experience as to the convenience and efficiency of the stoker method of firing. . . The replies would be difficult to summarize. In general the stoker users reported satisfaction with their stokers, making particular reference to economy, efficiency, and saving of labour in their operation. Attention was called to the need for tight furnaces, good adjustment, etc., and some references were made to dust and fly ash, etc. A sound furnace, a good stoker installation, and a steady supply of a suitable coal are evidently three prime requisites for complete satisfaction.

SUITABILITY OF ALBERTA COALS FOR USE IN AUTOMATIC DOMESTIC STOKERS

Coals Arranged by Groups and Areas

The following comments are based principally upon the behaviour of the coals in the stoker tests made, and upon consideration of the answers received to the questionnaire. It is fully realized that many more coals would have had to be tested, and a more comprehensive set of replies received, to ensure reliability. Nevertheless the need for information on the suitability of the different coals for use in the different stokers has made it imperative that the available information should be published without further delay.

It must be clearly understood that the omission of any coal area from the following list does not mean that the coal is unsuitable for stoker use, but does mean that specific information was not available.

Stated elsewhere, it must be reemphasized here, that, owing to wartime and other conditions, the coals obtained for tests, or reported on in answers to the questionnaire, frequently were not of the quality that could be supplied for the stoker market, either in respect to cleanliness or to sizing. Many comments are therefore less favorable than they should have been.

Under each area is indicated the source and extent of the information on which the comments are based. Typical ash fusion temperatures are taken from Table 22, page 174, Report 35, Coals of Alberta. Typical analyses are not given, but can be found for each area in Part VI of the same report. Maps of the coal areas of the Province are also given in Report 35.

In the underfeed stoker employed in this investigation, as with the majority of underfeed stokers, the planned method for the removal of ash from the furnace is as clinker picked up by tongs provided for the purpose. Criticisms of coals for their failure to form a firm clinker would not be applicable to the use of the same coals in underfeed stokers provided with mechanical ash removal.

The standard that was set for the operation of the underfeed stoker, in the investigation, that all refuse should be removable by tongs, was apparently too exacting since the questionnaire showed that many underfeed stoker users supplemented the tongs by the use of a small shovel to take out loose ashes from time to time as required, and that they took little or no exception to the necessity for this.

It is impossible to give definite information as to the clinkerability of the coals in any area, because this may vary from mine to mine or even from one consignment to another from the same mine, and because the same coal may not behave the same in different stoker installations. This must be kept in mind whilst reading the following comments. For explanation of smoke test results reported see Appendix 5.

The coals of Alberta may be divided into five broad groups, each containing coals of the same general character and used for the same purposes, as shown on Pages 19 and 20 of Report 35. In the following section the coal areas are listed alphabetically under their respective groups. An analysis is given for each group, but it must be understood that, as there is a wide range of coals in each group, the analyses given is merely typical and may be far from representative of some coals in the group.

Group I.

Semianthracite and Low Volatile Bituminous Coal (New Canadian Classification).

Low volatile, non-coking coal from mountain areas. Commonly called steam coal.

A good storage, weather resistant coal. Burns with a short, slightly smoky flame. Used for railways and for steam raising in general. This coal, when briquetted, is also used for domestic heating.

Important areas where this coal is or may be mined are: Cascade, Highwood, Nordegg.

Typical analysis: Moisture %, 1½; Ash %, 8½; Volatile matter %, 15; Fixed carbon %, 75; Heat value, B.t.u./lb., 14,000.

Coals of this group may be considered for underfeed, but not for overfeed stokers. Smoke test results, on 10 samples, ranged from 0 to 42%.

Cascade Area Coals.—Reported typical ash fusion temperatures, from 2140° to +2770°F.

Two samples tested in the underfeed stoker; no reports received from questionnaire.

The coal failed only in suitability for clinker removal by means of tongs, and would appear to be entirely suitable for an underfeed stoker with mechanical ash removal. The coal can be made to give a satisfactory clinker for removal by tongs either by addition of iron oxide or by blending with a coal of lower ash fusion temperature, as described in Appendix 4.

Group II.

Medium Volatile Bituminous and High Volatile A Bituminous coals. (New Canadian Classification.)

High volatile, coking bituminous coal from mountain areas. Also commonly called steam coal.

A good storage, weather resistant coal. Burns with a medium to long, smoky flame. Used for railways and for steam raising in general. Also used for making coke, as smithy coal, and in the cement industry.

Important areas of this group are: Crowsnest and Mountain Park.

Typical analysis: Moisture %, 1½; Ash %, 12½; Volatiile matter %, 25; Fiixed carbon %, 61; Heat value, B.t.u./lb., 13,200. Coals of this group may be considered for underfeed stokers provided with anti-coking devices, but not for overfeed stokers.

Smoke test results, on 13 samples, ranged from 60 to 94%.

Crowsnest Area Coals.—Reported typical ash fusion temperatures, from 2,630° to +2,770°F.

One sample tested in underfeed stoker; no report received from questionnaire.

The coal gave trouble in the test stoker owing to its coking tendency and to its failure to clinker. A few preliminary blending tests were made without success.

Mountain Park Area Coals.—Reported typical ash fusion temperatures, from 2,280° to +2,700°F.

One sample tested in underfood stoker; one report received from questionnaire for underfeed stoker.

The coal gave trouble in the test stoker owing to its coking tendency and to its failure to clinker. A few preliminary blending tests were made without success.

Group III.

High Volatile B Bituminous and High Volatile C Bituminous Coals. (New Canadian Classification.)

High volatile, non-coking coal, principally from foothills areas.

A good storage, weather resistant coal. It is a free-burning, non-coking coal that burns with a long, slightly smoky flame. Used for domestic and for steam raising purposes. It is a strong coal and can be shipped and stored reasonably well.

Important areas of this group are: Coalspur, Lethbridge, Prairie Creek, Saunders.

Typical analysis: Moisture %, 10; Ash%, 10; Volatile matter %, 34; Fixed carbon %, 46; Heat value, B.t.u./lb., 10,900.

All coals of this group may be considered for underfeed stokers but only the high volatile C bituminous coals for overfeed stokers.

Smoke test results, on 15 samples, ranged from 52 to 90%.

Coalspur Area Coals.—Reported typical ash fusion temperatures, from 2,050° to 2,450°F.

One sample tested in both stokers; eight reports for underfeed stokers, and one report for overfeed stoker, received from questionnaire.

The samples tested had too high an ash for complete satisfaction, and the same fault was mentioned in some questionnaire reports. The indications are that these coals could be used satisfactorily in either type of stoker, but some clinker trouble might be found.

Lethbridge Area Coals.—Reported typical ash fusion temperatures, from 2,060° to 2,420°F.

Two samples tested in both stokers; no reports received from questionnaire.

Both samples tested had too high ash for complete satisfaction, but worked well in the overfeed stoker. The indications are that these coals could be used satisfactorily in either type of stoker, but some clinker trouble might be found.

Pekisko Area Coals.—Reported typical ash fusion temperatures, from 2,150° to 2,550°F.

No sample tested; one favorable report received from questionnaire for use in underfeed stoker. In all probability the coals of this area could be used satisfactorily in underfeed, but not in overfeed stokers.

Saunders Area Coals.—Reported typical ash fusion temperatures, from 2,010° to 2,260°F.

One sample tested in both stokers; seven reports received from questionnaire for use in underfeed stokers.

The indications are that these coals could be used satisfactorily in either stoker.

Group IV.

Subbituminous A and Subbituminous B Coals. (New Canadian Classification.)

A so-called domestic coal, fair storage, from prairie areas.

Can be stored, with care, under cover. It is a free-burning, non-coking coal, that ignites easily and burns with a long, smokeless flame. Used for domestic heating and also for steam raising. It can be shipped in box cars.

Important areas of this group are: Brooks, Carbon, Drumheller, Edmonton, Pembina, Taber.

Typical analysis: Moisture %, 19; Ash %, 7; Volatile matter %, 30; Fixed carbon %, 44; Heat value, B.t.u./lb., 9,700.

Coals of this group may be considered for either underfeed or overfeed stokers.

Smoke test results, on 8 samples, but with no subbituminous A coals included, ranged from 0 to 46%.

Brooks Area Coals.—Reported typical ash fusion temperatures, from 2,130° to 2,370°F.

One sample tested in overfeed stoker; one report received from questionnaire for use in underfeed stoker; these coals might be expected to burn well in either stoker.

Carbon Area Coals.—Reported typical ash fusion temperature, from 1,970° to 2,400°F.

One sample tested in both stokers; five reports for underfeed stokers, and two for overfeed stokers, received from questionnaire.

Tests in both stokers were satisfactory but clinker trouble is possible with these coals.

Champion Area Coals.—Reported typical ash fusion temperatures, from 1,900° to 2,180°F.

No sample tested; one report received from questionnaire for underfeed stoker.

Information insufficient for report; but coals from this area may be presumed to be satisfactory for either stoker, except for possible clinker trouble.

Drumheller Area Coals.—Reported typical ash fusion temperatures, from 1,850° to 2,370°F.

Two samples tested in both stokers, and one additional sample in overfeed; seventeen reports for underfeed stokers, and four reports for overfeed stokers, received from questionnaire.

One overfeed stoker test was entirely satisfactory, but in other tests clinker trouble was experienced. The questionnaire indicated that whilst a number of users were quite satisfied others had clinker trouble.

Coals from this area are satisfactory for either stoker, except for possible clinker trouble.

Edmonton Area Coals.—Reported typical ash fusion temperatures, from 1,970° to 2,470°F.

One sample tested in both stokers and another sample in overfeed only; twenty-four reports for underfeed stokers, and thirteen reports for overfeed stokers, received from questionnaire.

One sample tested was satisfactory in both stokers, except for a rather high ash content. The other sample which was not a stoker coal, was not satisfactory. The questionnaire replies mainly reported satisfactory use in both stokers; but some complaints were made as to excessive ash and clinker trouble.

Coals from this area are satisfactory for either stoker, except for possible clinker trouble.

Pembina Area Coals.—Reported typical ash fusion temperatures, from 2,280° to 2,460°F.

One sample tested in both stokers; three reports for underfeed stokers, and one report for overfeed stoker, received from questionnaire.

The sample tested was generally satisfactory for both stokers, but did not clinker sufficiently, for refuse removal by tongs only, in the underfeed stoker. Questionnaire replies referred to clinker trouble.

Coals from this area would probably be satisfactory for either stoker, except for possible clinker trouble.

Taber Area Coals.—Reported typical ash fusion temperatures, from 1,870° to 2,490°F.

One sample tested in both stokers, no reports received from questionnaire.

The sample tested burned well in the overfeed stoker; but was not satisfactory in the underfeed stoker tests as it did not clinker. The ash content of the sample was rather high, and had a high fusion temperature. Coals from this area would probably be satisfactory for either stoker, except for possible clinker trouble.

Group V

Subbituminous C coal and Lignite. (New Canadian Classification.)

A so-called domestic coal, poor storage, from prairie areas.

Will not store well. It is a free-burning, non-coking coal, that ignites easily and burns with a long smokeless flame. Used for domestic heating and also for steam raising. It can be shipped in box cars.

Important areas of the group are: Camrose, Castor, Redcliff Sheerness, Tofield.

Typical analysis: Moisture %, 27; Ash %, 7; Volatile matter %, 28; Fixed carbon %, 38; Heat value, B.t.u./lb., 8,300.

Coals of this group may be considered for either underfeed or overfeed stokers.

Smoke test results, on 5 samples, but with no lignite coals included, ranged from 2 to 9%.

Camrose Area Coals.—Reported typical ash fusion temperatures, from 1,980° to 2,380°F.

One sample tested in overfeed stoker; five reports for underfeed stokers, and eight reports for overfeed stokers, received from questionnaire.

The sample burned well in the overfeed stoker; questionnaire replies indicated satisfactory use in both stokers, except for some reference to clinker trouble.

Coals from this area are satisfactory for either stoker, except for possible clinker trouble.

Castor Area Coals.—Reported typical ash fusion temperatures, from 2,010° to 2,360°F.

No sample tested; five reports for underfeed stokers, and one for overfeed stoker, received from questionnaire.

Questionnaire reports generally satisfactory, but some complaints as to ash and clinker.

Coals from this area presumably are satisfactory for either stoker, except for possible clinker trouble.

Pakan Area Coals.—No reported ash fusion temperatures.

No sample tested; one favorable report received from questionnaire for use in overfeed stoker.

Redcliff Area Coals.—Reported typical ash fushion temperatures, from 1,880° to 2,120°F. Ash fusion temperature for the sample tested was 2,240°F.

One sample tested in overfeed stoker; no reports from questionnaire. The sample gave trouble with clinker.

Coals from this area might be expected to burn well in either stoker, except for possible clinker trouble.

Sheerness Area Coals.—Reported typical ash fusion temperatures, from 1,980° to 2,320°F.

One sample tested in both stokers; no reports from questionnaire.

Clinker trouble experienced with both stokers; otherwise the coal burned satisfactorily.

Tofield Area Coals.—Reported typical ash fusion temperatures, 2,050° to 2,270°F.

One sample tested in both stokers; no reports from questionnaire.

Clinker trouble experienced with both stokers; otherwise the coal burned satisfactorily.

Westlock Area Coals.—Reported typical ash fusion temperatures, from 2,050° to 2,240°F.

No sample tested; one favorable report from questionnaire for use in underfeed stoker.

SUMMARY AND CONCLUSIONS

The investigation here reported was designed only to ascertain Alberta coals suitable for use in underfeed and in overfeed domestic stokers. No attemupt was made to determine efficiencies or to adapt the stokers to the coals.

Many difficulties were encountered, and the investigation was far from complete; nevertheless it has been thought better to publish now the information gained, in view of the present need for such information.

The investigation was carried out in wartime, when, owing to labour shortage and other difficulties, the marketing of a uniformly good coal was difficult.

The principal difficulties experienced during the test runs and revealed by the questionnaire, were difficulties due to unsatisfactory clinkering properties, and to dirty coal. Some coals also were unsatisfactory owing to their tendency to coke. Clinker trouble may be of two kinds; in either stoker a clinker may be formed so hard and unporous as to stop the adequate supply of air to the fire; and in the underfeed stoker the ash may fail to form clinker sufficiently hard to be removed by tongs, which is the preferred method of ash removal in many, but not all, underfeed stokers.

The exact evaluation of the clinkering property of any coal is rendered difficult or impossible because different consignments of the coal from the same mine may differ in character, and because the same coal may behave differently in two different installations even of the same make of stoker. General conclusions, however, are possible. From certain areas no coals can be expected to clinker, whilst from others most of the coals are likely to form hard clinker too readily.

Supplementary investigations with regard to the control of clinker formation and of coke formation, and as to the smokiness of coals were included in the investigation and are described in appendices.

Tests made in the underfeed stoker with a Kentucky coal, said to have been sold in wartime for stoker use in Eastern Canada, were far from satisfactory with respect to clinkering, coking and smoke; and the tests were suggestive that with careful selection and preparation of a suitable Alberta coal, a notable part of the eastern market might be won for Alberta, if the Kentucky coal tested was a typical sample of the supply to that market.

The ordinary automatic domestic stoker is essentially a makeshift piece of apparatus, as it has been designed for installation in existing furnaces. It appears certain that well designed and constructed stoker-furnace units will eventually replace the present stokers. If, as seems likely, the new units have a simple system for ash removal, for which a clinkering coal is not desirable, the new units will be easier to supply with satisfactory stoker coal. The tongs system for refuse removal has many advantages and advocates, nevertheless its adoption has the disadvantage of narrowing the specifications for a satisfactory coal. New units are also likely to be made available capable of burning coking coals.

If a stoker installation is carefully made, in a good, air-tight furnace, with the necessary controls, and with both stoker and furnace properly sized for the heat requirements of the house, it is likely to give lasting satisfaction to the householder, if he can count on always obtaining a satisfactory coal. Moreover, each satisfied user is likely to result in other installations.

The crux of the situation lies in the regular supply of a satisfactory coal. The present market for stoker coal is not very large, but it is a worthwhile market and it is, and can be made even more, an expanding market. An obvious solution would be that in each coal field a limited number of operators should arrange to make a specialty of the supply of stoker coal. The coal should be correctly sized, perferably cleaned or washed, and care taken to exclude spikes, chips of wood, etc. The coal could then be oiled to obviate dust trouble. The operator should be prepared to state that his coal was unlikely to give trouble due to the formation of a hard clinker; and to state that his coal would or would not suit a customer who used tongs for removal of refuse. The coals thus prepared and sold should include cheap coals for home markets and high heat value coals for more distant markets.

No suggestion is made as to the method to be employed in the selection of the limited number of operators. In the first place, however, only those operators should consider the market whose coals are naturally suited to the requirements and their number would be further limited to those willing to make the needed investment for doubtful returns. The prospect for good coal to the consumer and profit to the operators would be seriously impaired if the number of operators became too large.

The replies to the questionnaire showed too many consumers who at one time or another had received unsatisfactory deliveries of stoker coal. The investigation as a whole showed the availability of a considerable number of coals suited to the underfeed stoker, and of coals suited to the overfeed stoker, in the home markets. No high heat value coal was found suited to all underfeed stokers in the distant markets; but methods for controlling clinkering characteristics to suit the needs, were examined and found encouraging.

APPENDIX I.

Underfeed Stoker—Test Installation

The underfeed stoker used in this investigation was a Fairbanks-Morse Victory Model. It had a rated capacity of 25 pounds of coal per hour, and a hopper capacity of approximately 400 pounds. In the test runs made the actual coal consumtion per hour of feeding varied from 13.6 pounds with a high heat value coal to 28.6 pounds with a low heat value coal.

The furnace employed was a steel furnace 23 inches in diameter at the grate level and 37 inches from grate level to crown. Fig. 4 shows the general set up of the stoker and furnace. The use of this furnace with the stoker was approved by the representative of the stoker manufacturer. The estimated radiation surface was approximately 34 square feet, which is rated as being capable of heating approximately 25,000 cubic feet of house space through a Canadian winter.

The furnace was connected by an eight inch diameter flue pipe to one flue of a chimney 25 feet high. The flue was lined with an 8 inch square tile pipe. For mild weather use an eight foot, sheet iron extension was added to the chimney.

To install the stoker the grates were removed, and rectangular holes 10½ inches high and 12 inches wide were cut in the outer casing and in the side of the steel furnace proper. Into these holes a galvanized iron box 10½ inches high, 12 inches wide, and 14 inches long was tightly fitted. This box constituted a passage through which the retort and its connections could be inserted into the fire pot of the furnace. One end of this box was attached to the furnace wall and the other end projected about six inches outside the furnace casing.

The rectangular retort of the stoker, 10¾ inches wide, 12¼ inches long and 9½ inches high, rested on the furnace base. Sand was packed around the retort and in the above box around the air duct, auger tube, and clean-out tube; the sand packing served as a heat insulator and as a support for a sloping hearth, made of fire clay and cement, about two inches thick. This hearth at the periphery of the retort was at the level of the lower edge of the outside ring of tuyeres and sloped up from the retort to the furnace wall at an angle of about 15° from the horizontal.

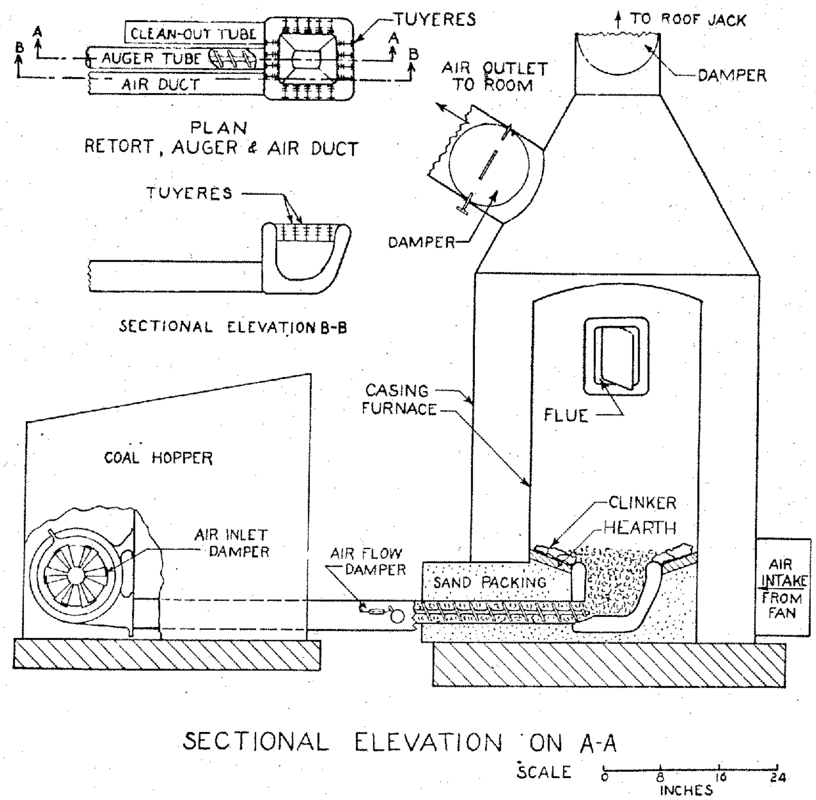

Fig. 4.—Underfeed Stoker and Furnace

The height from the tuyere ring of the retort to the lower edge of the opening into the flue pipe was 24 inches and from the tuyere ring to the crown of the furnace was 39 inches. The grate area, that is the total area of the four tuyere plates capping the retort walls, was approximately a square foot; the area of the air ports in these tuyere plates was one tenth of this.

The hopper stand, which also carried the motor, fan, gearing, etc., was set on one cement base and the furnace on another. These were built so that the stoker was level. All joints in the auger tube, air duct, and clean-out tube were sealed with furnace cement.

This stoker was equipped with a shear pin, a clean-out plate, and a "Firetrol" air damper in the air duct designed to automatically adjust the air flow as required by changing fuel bed level.

The heat generated in the furnace was absorbed by air supplied by a fan. The fan, placed near the base of the furnace, forced some 2,100 cubic feet of air per minute in through an opening in the furnace casing. There were two exits for the air in the crown of the casing; the main exit led through a double roof jack to the outside of the building, but a secondary exit permitted the passage of heating air into the building. The two exits were damper controlled. This forced air system was necessary to replace the natural air circulation of an ordinary domestic installation.

APPENDIX II.

Overfeed Stoker—Test Installation

The overfeed stoker used in this investigation was an "Alberta Coal Stoker" made by Coutts Machinery Co. Ltd., Edmonton, and loaned by them for the tests. It was rated at 30 pounds of lignite per hour and its hopper capacity was about 300 pounds. In the test runs made the actual consumption per hour of feeding varied from 18.2 pounds to 27.2 pounds of subbituminous and higher rank coal. The feed rate was varied with the heat value of the coal.

The furnace employed was a cast iron furnace 15 inches in diameter at the grate level and 32 inches in height from grate level to crown. Fig. 5 shows the general set up of stoker and furnace, and Fig. 6 shows details of the foundations and ash pit. The use of this furnace with the stoker was approved by the stoker manufacturer. This furnace had an estimated radiation surface of 25 square feet with Canadian winter capacity for about 14,000 cubic feet of house space. The furnace is shown as it was first installed; later, however, the top part of the furnace was turned through 120° so that an observer could look through the fire door of the furnace and see the fire on the retort of the stoker. The furnace was connected by an eight inch diameter flue pipe to a 25 or 33 foot chimney as described in Appendix I.

To install the stoker in this furnace, the grates were removed but, as the stoker was inserted through the ash door opening, no holes needed cutting in the furnace wall or casing. However, a hole was cut in the furnace base plate to allow coal ashes to fall into an ash pit provided in the foundation. The retort was held in place by a sheet steel collar, which also served to close the ash door opening. All joints were sealed with furnace cement.

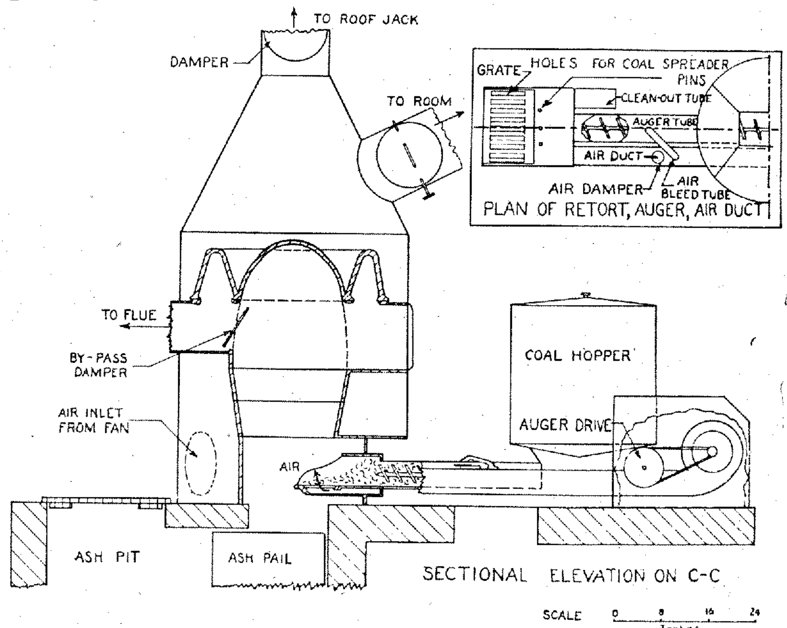

Fig. 5.—Overfeed Stoker and Furnace

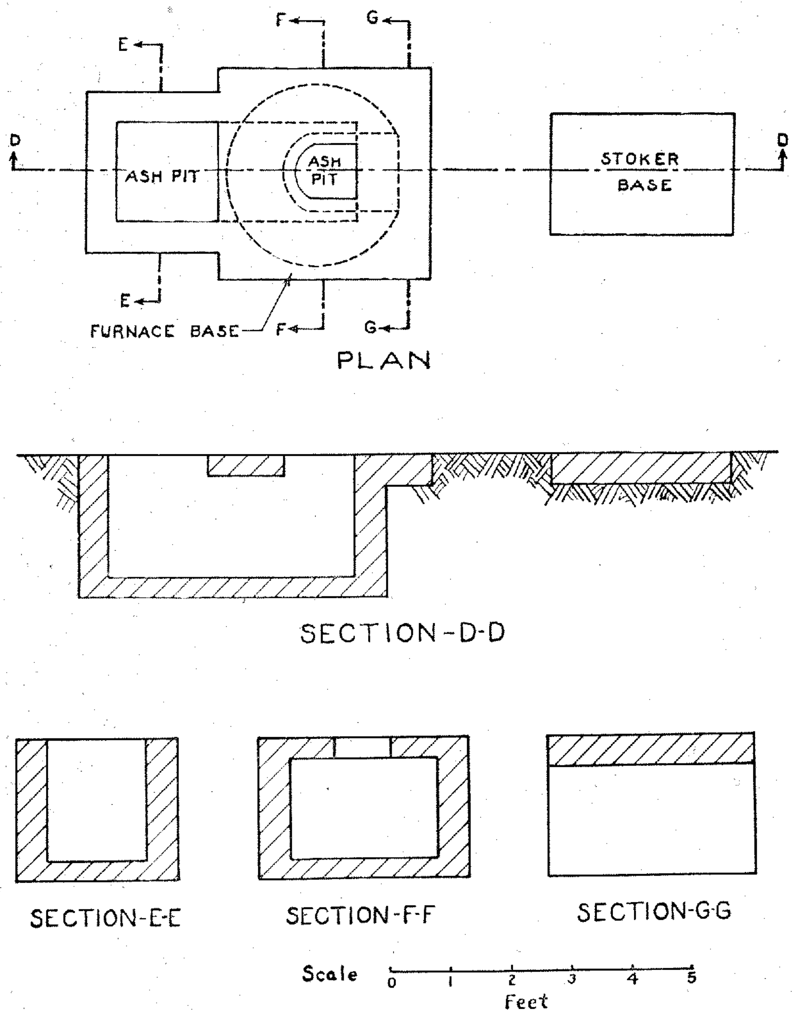

Fig. 6.—Plan and Sections of Foundation for Overfeed Stoker and Furnace

The discharge end of the retort was directly over the ash pit and ten inches from the opposite wall of the fire pot of the furnace. The grate was 40 inches below the crown of the furnace and 22 inches below the bottom of the flue exit. The grate area was approximately one half a square foot, with the air openings between the bars constituting one fifth of the whole area.

The coal hopper, motor, fan, and gearing were carried on a concrete base, separate from, but at the same level as, the base of the furnace. The clearance between the auger tube and auger was such that no trouble was encountered due to obstructions.

The arrangements for absorbing heat from the furnace by means of forced air were similar to those for the underfeed stoker as described in Appendix I.

APPENDIX III.

Testing Equipment

Testing equipment, as described below, was provided (a) to facilitate correct adjustment of coal and air prior to test runs, (b) to give the desired on and off periods for the test runs to be made, (c) to record any irregularities during a test run, (d) to prevent overloading of motors and overheating of furnaces and equipment, (e) to collect fly ash, (f) to measure combustion bed temperature, and (g) to record the distance that a coal burned back into the auger tube during the 58 minute off periods.

(a) A Ranarex, density balance, carbon dioxide recorder was used in the preliminary work on each coal to secure a suitable air setting for the selected coal feed. This recorder was also used in many runs, particularly in those of the underfeed stoker, as a check record on the regularity of furnace operation.

(b) The regular means of controlling the operation of a stoker, i.e., by a house thermostat, was impossible in the investigation. Each stoker was therefore electrically controlled through a relay switch actuated by the following timing device, constructed from a spring driven recorder that contained a drum which rotated once every two hours. The drum was covered with a thin sheet of metal over which was placed a sheet of celluloid. Two metal fingers, one for each stoker, were arranged to press lightly on the drum as it rotated. Slots cut in the celluloid permitted periodic electric contact between the metal sheet and a metal finger, whereby the corresponding relay switch was closed and stoker motor operated. Seven series of these slots were cut of the requisite lengths to allow either stoker to be driven at any one of the periodicities mentioned; the fingers were moved sideways to ride over the desired series of slots. Fig 7. shows this timing device. The resistance in the relay circuit was so high that little sparking occurred with the making or breaking of current through the metal finger. To further minimize this sparking quick makes and breaks were arranged by depressing one end of the exposed metal below the surface of the

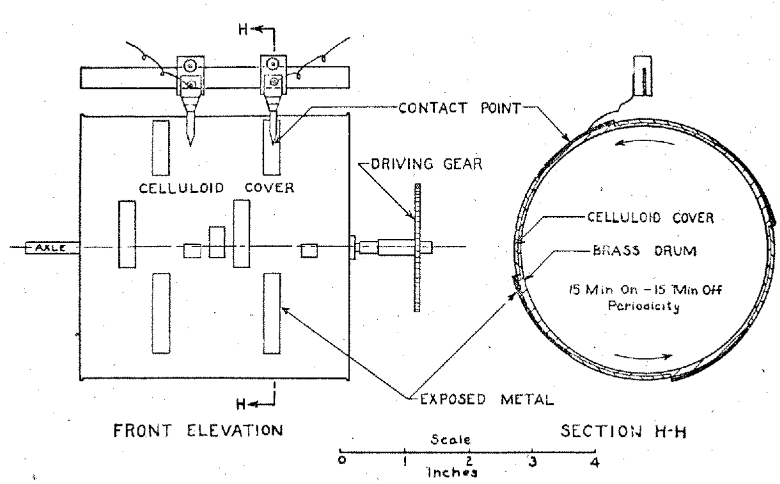

Fig. 7.—Timer for Periodicity Control

celluloid and by raising the other end above the celluloid level. Thus the metal finger dropped about a thirty-second of an inch as it made contact and again as it broke contact.

Each stoker was equipped with a switch by which the timing device could be by-passed to give continuous stoker operation. This switch was used in the preliminary work prior to a test run being started.

(c) Recording thermometers (°F.) were used to record both the flue and the warm air temperatures of each furnace. It was not intended to use these recorded temperatures for calculating efficiencies, but rather as evidence of the regularity (or irregularity) of furnace operation.

(d) The warm air temperature recording thermometers, having comparatively low maximum temperatures, were protected by means of "airstats" which were set to stop the operation of the stoker before the range of the recording themometers was exceeded. Actually these only operated on the few occasions when there was trouble with one or other of the cooling air fans.

(e) Fly ash produced by coals under forced draft contains particles of notably different size and weight so that no trap of simple design will retain all the fly ash raised from the combustion bed. Nevertheless a fly ash trap, shown in Fig. 8, was inserted in the flue pipe of each furnace. The weight of fly ash collected during a run gave a relative measure for each coal burned of its tendency to form fly ash.

The two main features of this trap are: the baffle placed crosswise to the flow of flue gases, and the removable bottom which permitted weighing the fly ash collected.

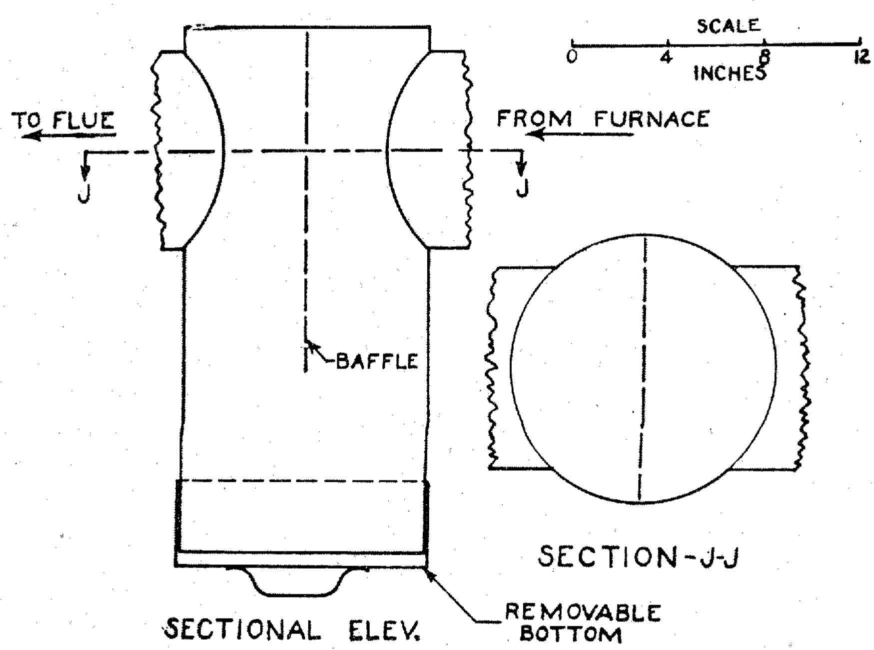

Fig. 8.—Fly Ash Trap

These fly ash traps were not installed until after tests on the first eleven samples were completed. Until that time fly ash had been measured by weighing the amount deposited in a small silica dish 3 inches in diameter and ½ inch deep. In the overfeed furnace the dish was placed inside the fire door directly under the flue gas entrance to the radiator. In the underfeed furnace the dish was placed in the clean-out pipe at the bottom of the radiator.

(f) A chromel-alumel thermocouple in a protective shield was first used to measure the combustion bed temperatures. The life of a thermocouple was very short and hence an optical pyrometer was used in later tests.

(g) Numerals were painted with a temperature sensitive paint, which changed color at approximately 160°F., on a white background on the auger tube of each stoker at two inch intervals. These numerals served as a check on how far back into the auger tube a coal burned during the 58 minute off periods. This paint was made by mixing into a paste with oil two parts of mercuric iodide and one part of cuprous iodide.

APPENDIX IV.

Ash Content of Coal and Control of Clinker and Coke Formation

All coals contain mineral impurities which form ash when the coal is burned. Clean coal is particularly desirable for stokers and since much ash on the grate may tend to interfere with regular combustion, unburned coal may be carried away with the refuse; and the higher the ash the greater the work involved in operation of the stoker. It is, however, possibly worth noting that an extremely low ash coal may be unsatisfactory as the presence of ash tends to prevent the burning of the grates or tuyeres. The loss of combustible with the refuse need not be serious. In 38 runs, with 12 coals, in the underfeed stoker the average loss of coal with the refuse was less than 0.2%. In 33 runs with 11 coals in the overfeed stoker the average loss of coal was 1.6%. However, when calculating the latter figure, runs with 6 coals were omitted as these coals gave serious clinker trouble, with consequent irregular combustion and fuel losses of up to 9%.

More important, however, than the actual amount of ash left when a coal is burned is the clinkering characteristics of that ash. If the ash has a softening or melting temperature which is lower than the temperature attained in the fire, then that ash may be expected to bind together to form a more or less hard mass known as clinker. Two kinds of clinkering trouble may be experienced. In the underfeed stokers dependent upon removal of refuse from the furnace by tongs, a coal is not satisfactory unless the ash forms a clinker strong enough to be so removed; whilst with any stoker a coal is not satisfactory if the ash becomes so fluid in the fire that it forms a hard, non-porous clinker that interferes with the passage of air to the fire and thus causes irregular combustion.

The fusibility of a coal ash sample can be determined in the laboratory by making a small cone out of the finely pulverized ash and heating this cone in a mildly reducing atmosphere, under closely specified conditions, in a suitable furnace. Three temperatures are noted—the first, or temperature of initial deformation, is the temperature at which the first rounding or bending of the apex of the cone takes place. The second or softening temperature, often regarded as the fusion temperature of the ash, is the temperature at which the cone has fused down to a spherical lump. The third, or fluid temperature, is the temperature at which the cone has spread out over the base in a flat layer.

There is such a large difference between the fusion of finely pulverized coal ash under the specified conditions in the ash fusion test, and the fusion of the heterogeneous particles of mineral matter as they occur and touch each other in the stoker furnace, that it would be surprising if the ash fusion temperatures gave a complete picture of the clinkering characteristics of a coal. Actually, however, these temperaturee give a useful indication of probable clinker formation. Fieldner and Selvig, of the U.S. Bureau of Mines, have suggested three classes of coal fusibility. Class 1, refractory ash, with softening temperatures above 2,600°F. Class 2, ash of medium fusibility, with softening temperatures between 2,200 and 2,600°F. Class 3, easily fusible ash, softening below 2,200°F. Class 1 ashes are generally non-clinkering in furnaces, whilst Class 3 ashes will usually form hard, glassy, non-porous clinkers. Ashes in Class 2 are likely to clinker but the amount and character will depend on a number of factors varying with the coal and with furnace conditions. Table I shows the ash fusion temperatures, for a number of samples of Alberta coals.

The clinkering character of an ash must fundamentally depend on its chemical analysis, and a number of these analyses are also shown in Table I. Attempts have been made to correlate analyses and clinker formation, and broad generalizations are possible, but so many factors are involved that no close correlation has yet been made. The analyses can be used to suggest, for individual coals, suitable means to increase, as discussed later, or to decrease the ash fusibility. The chemical analysis of a coal ash is a long and costly operation, and this partly explains the small number of analyses available. Determinations of ash fusibility temperatures are less costly and far more are available; typical values found for each coal area in the Province are given, page 174, Report 35, Coals of Alberta.

When testing different Alberta coals in the Fairbanks-Morse undeerfeed stoker a number of coals, suitable for shipping to nearer markets, were found with satisfactory clinkering character. But no coal with high heat value, suitable for shipping to distant markets, was tested that formed a clinker that could be removed by tongs. Several methods were therefore studied by which clinkerability could be modified.

The first involved the addition of an iron compound to the coal, to increase the fusibility of the ash. This is a process developed and patented by the Bureau of Mines at Ottawa. They found that coals having a lime content in the ash of below 6% can be made satisfactorily clinkering if the ratio of the percentage of silica plus alumina in the ash to the percentage of iron (ferric) oxide in the ash is adjusted to between 4 and 6.

The best method for distributing the powdered iron compound over the coal and holding it there, was found to be as part of an oil treatment for dedusting. The oil held the iron on the surface of the coal. Two consignments of coal, from the same mine in the Cascade area, were treated by this method. The first consignment with a low ash content required an addition of only 0.7% of iron oxide to the coal. The second consignment had a slightly higher ash content and a different ash analysis which showed the need for the addition of 1.7% of iron oxide to the coal. The treated coals proved excellent stoker fuels, giving smooth combustion, and a clinker easily removed by tongs. The ash fusion temperatures of the original coals were above 2,690°F., whilst those of the treated coals were 2,440° and 2,370°F. respectively.

An attempt was made to place the iron oxide treatment within the control of the householder, as by the spreading of occasional spoonsful of the oxide over the surface of the fire. This method was not successful as the oxide did not reach the lower zone in the fire where the clinker ordinarily forms.

Another non-clinkering coal treated by additions of iron oxide, was also a coking coal. The success of the treatment for clinker formation could not be ascertained, as coke formation prevented the maintenance of a good fire.

The second method for modifying clinkerability, involves the blending of the coal with another coal of lower ash fusibility. This method also permits the possibility of moderating any coking tendency of the coal.

One of the above consignments of coal from the Cascade area was blended with one-third of its weight of coal from the Camrose area. The blended coal also proved excellent stoker fuel, with good clinkering characteristics, although the ash fusion temperature was only reduced to 2,680°F. The heat value of the blended fuel, however, was ten percent lower than that of the original coal, a matter of some significance when shipping to distant markets, but even so was approximately the same as that of United States anthracite imported into Canada. Further tests might reveal other coals suitable for blending, smaller additions of which would prove effective.

In further tests the above mentioned non-clinkering, coking coal was blended with the same Camrose area coal in blends of 3:1, 2:1, and 1:1. The coking tendency was notably reduced only with the 1:1 blend, but even with this blend a satisfactory clinker was not produced. The notably different combustion characters of the two coals resulted in their burning in different zones in the fire so that the two ashes became segregated instead of fusing together. A few other tests were made along these lines, but time was not available for a systematic study of blending.

As already stated, a number of the coals obtained for test were too high in ash to be satisfactory for stoker fuels. It is reasonable to assume that both the termination of the war-time shortage of labour, and the development of a worth-while market for stoker fuels, will result in operators being able to give more attention to the preparation of a clean stoker coal, and possibly result in further installations of coal cleaning or washing equipment.

Table I.

FUSION TEMPERATURES AND ANALYSES OF ASH FROM ALBERTA COALS

Area	No.	Ash in Sample %	Fusion Temperatures Initial Deformation °F.	Softening °F.	Fluid °F.	Silica %	Alumina %	Ferric Oxide %	Calcium Oxide %	Sodium Oxide %	Potassium Oxide %	Sulphur Trioxide %	Unaccounted %
Big Valley	1	11.8	2400	2460	2600	52.3	27.6	2.8	11.8	3.6		0.1	1.8
Brooks	2	16.4	2240	2360	2550	55.9	25.9	3.0	4.0	3.9	0.5	4.5	2.3
Brule	3	16.7	+2600	+2600	+2600	59.2	28.6	3.6	3.5	0.4		0.5	4.2
Camrose	4	4.8	2010	2080	2370	36.3	21.9	7.6	19.3	5.4		6.0	3.5
	5	7.6	2060	2150	2370	38.1	28.9	3.1	13.3	5.9	0.6	7.5	2.6
Carbon	6	12.1	2220	2360	2550	50.1	26.5	4.1	9.5	3.4	0.4	3.2	2.8
Cascade	7	7.2	2060	2240	2370	36.1	31.7	14.5	2.8	4.3		0.1	10.5
	8	7.6	+2690	+2690	+2690	51.4	37.5	8.4	1.3	0.0	0.6	1.3	......
	9	10.5	+2690	+2690	+2690	58.5	33.4	2.6	2.0	0.5	1.2	2.2	......
see note†	10	8.3	2390	2440	2520	46.1	33.7	17.8	1.2	0.0	0.5	1.2	......
see note†	11	12.4	2280	2370	2670	49.0	27.9	18.5	1.7	0.4	1.0	1.8	......
see note†	12	9.8	2530	2690	+2690	53.4	32.3	2.8	4.8	1.8	1.0	3.6	0.3
Coalspur	13	14.4	2100	2180	2280	53.9	18.5	3.3	19.2	1.4	0.4	2.3	1.0
	14	......	2190	2220	2280	42.1	13.0	4.3	32.4	......	......	1.9	6.3
	15	......	2330	2420	2600	59.8	23.8	3.0	8.0	2.2		1.6	1.6
Crowsnest	16	13.8	2600	+2600	+2600	59.0	27.2	6.0	1.9	......	......	0.1	5.8
	17	17.4	2600	+2600	+2600	55.3	32.8	5.4	2.9	0.6		0.8	2.2
	18	18.5	+2690	+2690	+2690	55.9	33.7	7.0	1.9	0.2	0.5	2.0	......
Drumheller	19	8.5	1940	1990	2130	40.1	21.0	12.2	9.4	4.1	1.2	10.2	1.8
	20	10.2	1920	2090	2350	54.3	21.0	3.9	7.6	3.8	0.8	4.7	3.9
	21	11.0	2240	2300	2490	53.3	25.6	6.3	5.9	4.0	0.3	2.9	1.7
Edmonton	22	6.1	2120	2240	2370	46.8	21.6	4.0	18.8	5.3		0.9	2.6
	23	6.5	2100	2240	2370	55.2	21.7	5.0	9.9	4.4		1.9	1.9
	24	11.4	2300	2340	2520	54.0	24.5	4.1	8.2	4.7	0.3	4.9	......
	25	14.0	2340	2380	2530	51.5	30.5	2.0	8.1	2.6	0.4	2.6	2.3
Lethbridge	26	9.3	2060	2150	2330	49.2	18.6	5.2	13.8	4.0		3.8	5.4
	27	9.8	2150	2240	2370	45.7	24.1	7.6	12.7	3.7		3.5	2.7
	28	11.4	2190	2280	2390	52.6	25.6	5.4	9.0	2.1	0.4	4.2	0.7

	29	13.5	2240	2290	2420	52.9	27.1	5.1	7.5	2.0	0.8	4.5	0.1
see note†	30	7.7	2250	2270	2390	48.5	28.4	5.7	8.7	3.0	0.3	3.4	2.0
Mountain Park	31	12.9	2460	2600	+2690	59.0	29.9	2.2	4.6	0.8	0.8	2.2	0.5
Nordegg	32	14.5	2370	2510	+2600	53.1	26.4	5.2	6.2	2.2		3.6	3.3
Pembina	33	8.9	2350	2450	2570	41.3	29.7	4.6	18.7	0.1	0.5	3.5	1.6
Redcliff	34	14.8	2100	2240	2510	46.3	24.6	5.3	8.0	5.2	0.7	7.6	2.3
Saunders	35	8.8	2190	2230	2430	42.8	23.3	8.7	15.5	1.7	0.9	6.1	1.0
see note†	36	4.7	2210	2250	2290	39.5	28.3	10.7	10.5	2.5	0.5	6.2	1.8
Sheerness	37	7.2	2210	2240	2360	38.4	24.4	5.9	17.0	2.2	0.5	8.8	2.8
Taber	38	13.8	2280	2380	2550	49.4	28.7	4.1	5.6	1.9	0.8	5.4	4.1
Tofield	39	6.2	2060	2100	2150	28.7	29.8	5.1	18.9	4.8	0.5	10.6	1.6

NOTES: All temperatures rounded to the nearest 10°F. and all percentages to the nearest 0.1%. Determination of phosphorous pentoxide, magnesium oxide and titanium oxide were made only on a few samples; these and other minor constituents are included in the unaccounted for percentages. This table gives information not available at the time of the preparation of Table No. 9, in Report 35, Coals of Alberta. Thirteen of the above samples were from work prior to the present stoker investigation, but are here included to amplify the later information.

†Samples 10, 11, and 12 were from Cascade coal treated to increase fusibility of ash. Sample 10 was Sample 8 treated with iron oxide, Sample 11 was Sample 9 similarly treated, and Sample 12 was from a blend of 75% of Sample 9 and 25% of Camrose coal, Sample 5.

* Samples are from samples of coal cleaned by flotation on a heavy solution. Sample 30 is Sample 29 cleaned, and Sample 36 is Sample 35 cleaned.

It must be recognized that a cleaned coal from a mine may possibly have a different clinkering character than has the original coal. No washed coals were available for stoker tests, but ash fusion tests, and ash analyses, were made on three coals, and on the same coals after purification by floating on a heavy solution. Ash reductions from 17.0 to 7.3, from 13.5 to 7.7, and from 8.8 to 4.7%, respectively, were made. The resulting changes in the ash fusion temperatures were trivial, but the chemical analyses suggested that the clinkering character might be rather more changed than the ash fusion temperatures suggested. In general the ash from a cleaned coal is more fusible than that from the original coal; but the reverse is sometimes found.

The fact that the ash fusion characteristics and ash analysis of any coal may vary with the ash percentage of the sample explains why the ash percentage is shown in Table I.

APPENDIX V.

Evaluation of Smokiness of Coal

It is well known that almost any coal can be burned without smoke in well designed equipment, as for example in an underfeed stoker. On the contrary, almost any coal may smoke if burned under unsatisfactory conditions of furnace, feed or air supply. Nevertheless coals do vary materially in their tendency to burn with a smoky flame. It therefore seemed profitable to devise test apparatus and test procedure to evaluate the comparative smoke forming tendency of coals. The test was standardized to produce from any coal an amount of smoke comparable to that produced when the same coal was burned in the customary manner in an ordinary domestic furnace.

The apparatus consisted of a vertical tube, electrically heated, connected to a chimney, one section of which was horizontal. The tube temperature was regulated to 700°C. (1290°F.), and a definite weight of the test coal, carefully sized, was introduced near the bottom in a small, wire gauze cage. The coal caught fire and burned in the draft induced by the chimney. Any smoke evolved interfered with a parallel beam of light passing through the horizontal section of the chimney. The light was focussed at one end onto a photronic cell, which registered on a microammeter the intensity of the light falling thereon. Microammeter readings were taken every five seconds throughout the complete time from the introduction of the coal to the end of any smoke evolution—this was usually less than two minutes. The smoke forming tendency was recorded as the average percentage reduction of the light falling on the cell during the twenty seconds of greatest smoke density.

The results obtained indicated a satisfactory correlation of test results with smoke production in ordinary domestic practice; although even coals regarded as smokeless caused a slight interference with the beam of light.

Over fifty Alberta coals and one Kentucky coal were tested. These included all the twenty-three coals tested in the stoker investigation. It was found that there was a close correlation beween coal rank and smoke producion. The highest rank coals were smokeless, but, with decreasing rank, the observed smoke increased to a maximum with High Volatile A Bituminous coal and then decreased to practically no smoke with the low rank coals. The same relations can be correlated with the oxygen content of the coal—both low and high oxygen content coals are smokeless whilst intermediate coals are smoky. Smoke is produced from the volatile matter of the coal; but where this volatile matter has a high oxygen content it ordinarily will burn without smoke.

It is hoped to publish elsewhere a detailed description of this test and a study of the results obtained.

LIST OF RELATED PUBLICATIONS

OF

RESEARCH COUNCIL OF ALBERTA

EDMONTON, ALBERTA

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Report No. 34 (1943), in five parts, by J. A. Allan. Part V—Coal Areas of Alberta, pp. 36, and map No. 18. **Price 75 cents.**

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