STATE COLLEGE OF WASHINGTON
PULLMAN, WASHINGTON

EXTENSION SERVICE
W. S. Thornber, Director

Fuel Economy in Domestic Heating and Cooking

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LETTER OF TRANSMITTAL

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Director W. S. Thornber,
Department of Extension Service,
State College of Washington.

Sir: I have the honor to transmit herewith a bulletin on the subject, Fuel Economy in Domestic Heating and Cooking. This bulletin has been prepared by Professor B. L. Steele at the request of the faculty of the College of Mechanic Arts and Engineering. In view of his experience with a wide variety of experimental work in this field extending over the past ten years, I feel that his conclusions may be accepted with the fullest confidence.

Very respectfully,
H. V. Carpenter,
Dean, College of Mechanic Arts and Engineering, The State College of Washington.

INTRODUCTION

The United States Geological Survey estimates that the coal production in the United States for the year 1917 will probably exceed that of 1916 by more than 50,000,000 tons, and yet Dr. Harry A. Garfield, United States fuel administrator, announced recently that the increased use of coal in munitions factories and other war enterprises would entail a net shortage in the United States for the year of more than 50,000,000 tons and that this shortage must be made up by further increased production, curtailment of nonessential manufactures, and reduced consumption in the homes. It is further estimated that of the 650,000,000 or more tons which will be produced in 1917, approximately 125,000,000 will be used for domestic heating and cooking. During 1918, therefore, the consumption in the homes must be so reduced as to save probably as much as 15,000,000 tons. This bulletin is written in the hope that it may assist the people of the State of Washington in doing their share in this undertaking.

I.

COMPARATIVE DATA CONCERNING FUELS AND THEIR USES

Tables I. and II. give important information concerning fuels, which are fairly representative of those used in the State of Washington. This information should be valuable in purchasing and using fuel. Attention should be called to several considerations in connection with the items in the tables. In the first place, other things being equal,—e. g. cost, convenience in handling, and efficiency obtained in firing, **that fuel is best which yields per pound, when burned, the largest number of units of heat**—B. T. U.'s* Notwithstanding this fact, that particular coal which happens to yield when burned, **the largest bulk of ash,** is rated by many as the poorest coal, regardless of its other characteristics. Aside from the annoyance of having to handle the ashes, they are an advantage rather than a disadvantage, so far as the economical burning of the coal in stoves or house heaters is concerned, unless the percentage of ash is exceedingly high, above 10% to 12%. Furthermore, a little study of the table will show that the percentage of

*British Thermal Unit is the heat unit most used in engineering practice and is the quantity of heat absorbed by a pound of water when its temperature is raised one degree Fahrenheit.

moisture in the coal, which is not apparent directly to the purchaser or user, is perhaps of more importance in determining the value of coal than is the percentage of ash. The analyses given are taken from the reports of the United States Geological Survey and are for samples "as received" from the mine. The tests of Canadian coals are not official, but are apparently reliable. Attention is called to the four analyses of the sample of Mendota coal. These analyses show that in considering the analysis of a coal it is necessray to know whether the analysis was made "as received," "air dried," "dry coal," or "pure coal."

The fuel value of wood depends so much on whether it is green or dry that it is difficult to give a dependable statement of the heat equivalent of a pound of wood. However, 5800 B. T. U.'s per pound, the value given in the tables, is a good average for fairly dry Washington woods. Also, the weight of a cord of wood is a widely varying quantity, ranging from about 2100 pounds for dry pine to 3800 pounds for green tamarack. The average is probably about 2700 pounds per cord of well seasoned wood. 12,000 B. T. U.'s per pound may be taken as the average fuel value of the coals used in Washington. Hence, if wood and coal may be equally efficiently burned, a ton of coal is approximately equivalent in heating value to a cord and a half of wood.

When an electric current is used for heating, one kilowatt-hour of electric energy generates 3412 B. T. U.'s of heat.

Tests have shown that when a good grade of soft coal is burned in the ordinary warm air, steam, or hot water heaters used for residence heating, under the widely varying conditions demanded by the weather, and with the promiscuous methods of firing commonly used, on the average not more than 30% or 40% of the fuel value of the coal is utilized in heating the house. When anthracite coal, or any other fuel which has a high percentage of fixed carbon, is burned in a heater which has been properly installed and is economically fired by a competent fireman, the efficiency attained is between 50% and 60%, while with poor grades of coal and with incorrect installations and careless methods of firing, 75% or more, of the coal is wasted. In burning wood the efficiency is about the same as in burning a good grade of soft coal. Although in house-heaters lump coal may be burned slightly more efficiently than the finer sizes, the finer sizes are more economical usually because of the lower prices at which they may be purchased. When electricity is used for heating the efficiency is practically 100%.

TABLE I.

Name	Moisture	Volatile Matter	Fixed Carbon	Ash	B. T. U.
Washington Coals					
Issaquah	15.1	29.4	44.2	11.35	9.960
Grand Ridge	16.5	34.6	36.4	12.5	9.580
Renton	14.6	34.0	41.5	9.9	10.070
Blk. Diamond	7.4	39.3	49.2	4.07	12.500
Roslyn Cascade	3.1	35.6	50.0	11.27	12.850
Roslyn Fuel Co.	3.3	34.1	50.5	12.15	12.910
Cle Elum	7.9	34.6	44.8	12.68	11.410
N. W. Imp. Co.	3.1	35.6	49.9	11.37	12.860
Wilkeson	3.7	27.1	56.6	12.60	12.980
Carbonado	3.8	27.1	53.7	15.37	12.330
Wingate	4.0	36.9	52.7	6.41	13.280
Mendota					
As received	20.5	33.5	33.7	12.31	8.690
Air dried	10.2	37.8	38.1	13.91	9.820
Dry coal		42.1	42.4		10.920
Pure Coal		49.8	50.2		12.940
Utah Coals					
Castle Gate	6.13	40.07	45.45	8.35	12.217
Helper	4.47	40.79	49.98	4.76	12.982
Price	6.05	42.02	47.06	4.87	13.151
Wyoming Coals					
Rock Springs					
U. P. No. 11	8.53	35.6	50.39	5.48	11.833
U. P. No. 10	12.41	36.57	48.5	2.52	11.920
Kemmerer	5.86.	39.49	51.0	3.65	12.784
Owl Creek	17.04	35.53	45.10	2.33	10.991
Montana Coals					
Bear Creek	8.74	35.99	45.72	10.55	10.604
Red Lodge	11.69	36.14	40.19	11.98	9.787
Round Up	14.3	28.0	51.8	5.9	11.050
Canadian Coals					
Green Hill	1.5	23.4	63.8	11.3	13.700
Crows Nest	1.1	22.6	64.9	12.5	13.270
Corbin	3.5	25.5	59.0	12.0	13.000

Wood (Average Washington Woods) 5.800
Kerosene 19.980
Gasoline 20.250
Electricity (B. T. U. per Kilowatt hr.) 3.412
Gas (coal) B. T. U. per cu. ft 600

TABLE II.

Fuel	Price	Fuel Value B.T.U.	B.T.U for $1.00	Efficiency of heater	Utilizable B.T.U. for $1.00
Coal.......	$10.00 per ton	12,000	2,400,000	35%	890,000
Wood......	$10.00 per cord	5,800	1,595,000	35%	558,250
Electricity.	1c per KWhr.	3,412	341,200	100%	341,200
Electricity.	½c per KWhr.	3,412	682,400	100%	682,400

The following tables give useful information concerning **kitchen fuels, efficiencies of cooking equipments,** and **cooking costs** with various fuels. They summarize in part the results of some tests made during the past two or three years at the Home Economics Practice Cottage of the State College of Washington by the seniors in Home Economics.

Table III. gives the number of B. T. U.'s in one dollar's worth of each of the "fuels" used for cooking.

TABLE III.

Kind of Fuel	B. T. U.'s for $1.00
Coal @ $10.00 per ton*	2400000
Wood @ $10.00 per cord*	1595000
Kerosene @ 20c per gallon*	678570
Gasoline @ 25c per gallon*	492557
Electricity @ 3.85c per Kilowatt hr.*	88673
Electricity @ 3c per Kilowatt hr.	113730

*Prices in Pullman, Washington in December, 1916.

Table IV. gives the averages of a large number of tests on the efficiencies of various kinds of cooking equipment.

TABLE IV.

Kind of Equipment	Efficiency
Coal Range, (entire space utilized)	18%
Coal Range, (estimated for home cooking) about	2.5%
Flame contact burners (kerosene, gasoline) about	25%
Electric heaters, surface	45% to 65%
Electric heaters, enclosed	70%
Electric heaters, immersion	90%

Table V. gives the B. T. U.'s which are actually used when one dollar's worth of each of the "fuels" is burned, the various ranges operating at their average efficiencies.

TABLE V.

Fuel Fuel	Avreage B. T. U.'s for $1.00
Coal (range at 2.5% efficiency)	60000
Wood (range at 2.5% efficiency)	39875
Kerosene (range at 25% efficiency)	169640
Gasoline (range at 25% efficiency)	123215
Electricity (67% efficiency at 3.85 cts. per Kilowatt hr.	59380
Electricity (67% efficiency at 3 cts per Kilowatt hr.	76200

TABLE VI.

Cost of Cooking for Family of Five

Equipment	Average Cost
Coal Range, (water front connected*)	119.6 cts
Coal Range (water front disconnected)	77.4 cts.
Electric Range	78.5 cts.

*Coal at $10.00 per ton; electricity at 3.85 cts. per Kilowatt hour.

In table VI., is given the cost of cooking for a week for five persons on the electric range, on the coal range with the water front disconnected and on the coal range with the water front connected. Each value is the average of the results for several weeks' cooking. It may be observed that it cost 42.2 cents a week to heat the water for domestic use for this family of five with the water front on the coal range. These results were obtained during 1916-1917.

II.

HOW TO SAVE COAL IN DOMESTIC HEATING

Coal may be saved in domestic heating by using fuels other than coal, by heating only part of the house, by preventing unnecessary heat losses, by proper choice of heating equipment, by following correct practices in installing the heating equipment, and by following economical methods of operating it.

Using Fuels Other than Coal

At present prices, in the State of Washington, wood is practically the only fuel other than coal available for residence heating. Its use in those sections where it may be had locally is urged, for its use not only saves coal, but also saves transportation facilities. The local price in some sections may be such as to make it more expensive than coal. Reference to table II. above will enable one to calculate the prices for coal and wood which are equivalent. Regardless, however, of the relative cost of wood and coal, the use of wood, wherever possible, should be looked upon at present as a patriotic duty.

From the last column in table II. it may be seen that to heat a house with electricity at ½ cent per kilowatt-hour it costs about 50% more than to heat it with coal at $10.00 per ton. The use of electricity for heating is, therefore, for most families not practicable at present.

The relative value of these fuels at any other prices may be easily calculated.

Heating Only Part of the House

While it is a great convenience to have all the rooms of a house heated all of the time, it is to be regarded as a wasteful extravagance in the present crisis, for **on the average it takes between a ton and a ton and a half of coal to heat one room in an ordinary house during the winter heating season.** If during the period of the war every family, living in a large house, heated regularly only those rooms actually needed, thousands of tons of coal would be saved in a year in the State of Washington alone.

Preventing Unnecessary Heat Losses

In cold weather it is necessary to add heat to the rooms of a house continually in order to keep them warm because heat is continually and in part unavoidably escaping from the house to the outside; first, by direct transmission through the walls, windows, and doors; second, by the passage of warm air out through ventilating or stove flues; and third, by the filtration or diffusion of warm air through the walls and by the leakage of warm air out around doors and windows. The direct loss of heat, by conduction through a square foot of window, is four times as great as that through a square foot of wall of ordinary wood construction; hence a large part of the direct loss is prevented by using double glazed windows or by simply providing the windows with tightly fitting storm sash during the heating season.

In order to provide fresh air in the living rooms, part of the loss due to filtration through the walls and leakage around the doors and windows is necessary, but with the ordinary house construction the loss due to leakage around doors and windows is far more than necessary, particularly during windy weather. The storm sash just mentioned will prevent sufficiently the leakage around the windows, but if they are not used, the windows and doors should be provided with weather strips of some kind.

The amount of heat lost per hour from a house depends on the difference between the inside and outside temperatures. With an average outside temperature of 40° Fahrenheit, which is nearly the average temperature for the State of Washington from October to May, the amount of coal necessary to maintain a temperature of 68° is about 15% less than that to maintain a temperature of 72°. The average winter residence temperature in the State of Washington is probably about 72° or 73°; and it might be reduced to 68° if sufficient effort were made to humidify the air, for the amount of invisible moisture in the air determines to some extent the temperature at which a room seems agreeably warm. Dr. Henry Mitchell Smith makes the following statement as the result of many observations and experiments upon the sensations produced by different temperatures and percentages of saturations: "It may be accepted as a cardinal rule that if a room at 68° is not warm enough for any healthy person, it is because the relative humidity is too low." It has been found that for comfort at 68° the relative humidity must be about 44%. Much lower relative humidities are not only uncomfortable, unless accompanied by excessively high temperatures, but they are also detrimental to health. To bring the indoor relative humidity up to 44% in the drier sections of the State will require the evaporation of several gallons of water each day in the living rooms of the ordinary house. The saving of coal made possible and the effects beneficial to health which result make worth while any effort to humidify the air in living rooms during the heating season.

A very considerable saving of fuel may therefore be effected by the use of storm sash and weather strips, and by maintaining room temperatures 4° or 5° cooler than usual.

Proper Choice of Heating Equipment

The considerations presented here are of general interest, but are not especially helpful in the present situation, because in most cases the heating equipment is already installed.

The open fireplace is the most wasteful of all types of heating equipment. Its efficiency is probably never greater than 10% or 15%. It serves a good purpose on cool mornings and evenings and, when in use, is a good ventilator, but its artistic and aesthetic values furnish the chief justification for its existence in nearly any home.

If only one or two rooms of the house are to be heated, the heating may be done very economically with any one of the many excellent stoves on the market. One of the newer types in which special provisions are made for more complete combustion of fuel and for more nearly perfect control of the fire, and in which large radiating surfaces are provided, will give more economical results than some of the older forms. The stove should have a reversible grate if it is to be used for either coal or wood.

When the house is large and many of the rooms are to be heated much of the time, it is safer, cleaner, more convenient and probably more economical to use some kind of central heating plant. If the house is not too large, a warm air furnace properly installed is quite satisfactory, but for very large dwellings a hot water or a steam heating system will generally give better results. The first cost of a warm air furnace is much less than that of a hot water or steam heating system, but the life of either the steam or hot water equipment is usually considered to be several times that of the warm air furnace. Each of the types has some advantages over either of the others, but if they are properly installed and operated there is perhaps not very much difference in their fuel economies.

Installing and Operating the Heating Equipment

An essential part of any heating plant, no matter how simple or small, is a chimney of such size and height as to furnish an adequate draft. It is much better to have too much than too little draft, for proper use of dampers makes it posssible to control the fire in the former case, but not in the latter. Insufficient draft results in sluggish fires and often in the clogging up of the stove pipe or flue. To avoid trouble from wind blowing down the chimney, the chimney should extend several feet above the highest part of the roof.

In order that the draft may be properly controlled, it is necessary that all doors and dampers should fit practically air tight when closed; and in the case of furnaces, all cracks around the base or between sections or parts should be carefully puttied or cemented shut. Also a shut-off damper should be placed between the heater and the check draft door, or damper.

Some of the heat of the fuel is necessarily used in creating the draft. It probably amounts necessarily to 15% or 20%, but in many cases, due to improper methods of firing, a much larger fraction of the total heat of the fuel escapes up the chimney. Some of this chimney waste may be prevented by placing the heater as far from the chimney as the quality of the draft and the available space will permit and using a long smoke pipe to connect up the heater. This is particularly applicable to furnace installations. If the draft is sufficient and the firing is correctly done, the smoke pipe will keep itself clean and will furnish enough heat to keep the furnace room warm. Unless it is desirable to heat the rest of the basement, the heater itself and all hot water or steam pipes or warm air ducts run in the basement should be properly covered with a suitable insulating material.

It is highly important in heating with warm air furnaces that provision be made for the **re-circulation of the air.** A simple calculation will show that if the air is all taken in through the furnace from the outside it will take about a third more fuel than if the air is re-circulated.

To burn completely a pound of practically any of the coals used in the Northwest for domestic heating, approximately 160 cubic feet of air must be supplied to the fire. If less air is supplied the combustion is incomplete; if more air is supplied it is heated to a relatively high temperature and passes on up the chimney. In either case a serious loss of fuel may result. To insure complete combustion it is necessary to provide from 20% to 50% excess of air, but in many instances where holes are allowed to burn through the fire bed, or where doors and dampers do not fit, two or three times too much air may be used. This entails an additional chimney loss of probably more than 25% of the entire heat of the fuel. The following suggestions for firing apply either to stoves or furnaces and if observed will minimize most of the fuel wastes.

An even, steady fire should be kept during the part of the day and night when it is desired to have the house comfortably warm, between 65 degrees and 70 degrees Fahrenheit. The amount of coal fired and the amount of draft allowed will depend on the quality and kind of coal used and on the difference between the inside and the outside temperatures. In mild weather, a deep bed of ashes should cover most of the grate as it will tend to prevent too much air from getting through the grate. In severe weather the ash bed should be thinner and the bed of burning coal correspondingly thicker.

Whenever firing is necessary, and it should, if possible, always be done before the fire has burned too low, most of the glowing coal should be pushed to the back part of the fire pot and the fresh coal thrown into the front part near the feed door, leaving the bulk of the burning coal exposed, or to avoid moving the burning coal, the fresh coal may be fired alternately on opposite sides of the fire pot, particularly if the fire pot is circular. A large part of the volatile portion of the coal is driven off during the first half hour after firing, (particularly if small sizes of coal are used, or if the coal is non-coking,) and is ignited by the burning coal in the back part of the fire pot. This is important, for, if the fire happens to be completely covered with fresh coal, a large portion of this gas, which may represent a considerable fraction of the total heat of the coal, escapes unburned before the fire burns through and ignites it. And when it does burn through an undesirable explosion usually accompanies the ignition of the gases. Frequent explosions are indications of careless firing.

In heavy firing with coals rich in volatile matter, it is sometimes necessary to open the damper in the feed door for ten or twenty minutes just after firing to admit sufficient air to burn completely the large quantity of gases given off. In some stoves and furnaces a special so-called hot-blast damper is provided which is partly intended to serve this purpose. After these gases have been burned, the fire should be controlled largely by opening the check damper and by partly closing the shut-off damper rather than by completely closing the draft damper in the ash pit door, because this procedure tends to limit the leaking of air into the furnace around the feed door, if it does not fit properly, and through other small passages above the fire. It will probably be necessary also to close completely the ash pit draft damper in mild weather or on exceedingly windy days. With this method of control whatever air enters the furnace passes up through the fire. Except in emergencies the fire should not be checked by opening the feed door.

Firing should occur at fairly regular intervals, and with western coals, though less convenient, it will be found more economical to fire five or six times a day than to fire two or three times a day. Enough fire should be provided for the night to keep the house from cooling off too much, but it is poor economy to keep it as warm through the night as through the day, merely to avoid having to warm it up in the morning.

Frequent shaking of the grates till the fire shows through into the ash pit, is likely to result not only in an excess of air, but also in loss of unburned coal into the ash pit, particularly if fine coal is being used; therefore excessive shaking of the grates should be avoided. As a general rule, the fire should be poked very little from above unless a badly caking coal is used.

To insure free access of air to all parts of the grate and to prevent overheating of the grate bars by the accumulation of ashes up against them, the ashes should be removed every day, particularly when Washington coals are used, for nearly every one of them has a high percentage of ash. All surfaces over which the smoke and hot gases pass should be cleaned at least daily to prevent the accumulation of soot and ashes, for soot and ashes are very poor conductors of heat. This is particularly important in steam and hot water heaters. A layer of soot .01 inch thick is as effective in preventing the flow of heat from the hot gases to the water, as a layer of iron ten inches thick.

In general these same considerations apply to heating with wood. Owing, however, to the small amount and fineness of the ash and the coarseness of the wood, the control of the fire is more difficult. If wood is burned on a coal grate, it is generally necessary to close up completely a considerable part of the grate.

III.

HOW TO SAVE COAL IN COOKING

Although in general, coal may be saved in cooking in the same ways that it may be saved in heating, it is desirable to call special attention to the savings which may be effected by properly handling the kitchen fire and by using fuels other than coal for cooking.

Care of the Kitchen Fire

The fire box of the ordinary kitchen range is built large enough to carry a heavy continuous fire, such, for example, as is required by a large family on days when ironing and baking are being done. To make it smaller, so as to adapt it to the daily use of the average family, and to make possible better control of the draft, the grate should be kept covered with a thick layer of ashes. At some one place, at either one end of the grate or the other, or along the side next to the water-front, as the conditions may seem to require, the ashes should be raked thin, partly exposing a small area of the grate. Through this part of the grate most of the necessary amount of air will enter the fire, and over it the thickest part of the relatively small fire should be maintained, never allowing a hole to be burned through the fire bed. If a hole is allowed to burn through the fire the air passes largely through the hole, not through the fire, and the fire may actually go out. The thick bed of ashes brings the bed of glowing coals up near the top of the range where it is most effective. If a fire is desired over a considerable length of time, fresh coal should be added while there is yet a liberal supply of glowing coal, much of which should be pushed away from the thickest part of the fire and left uncovered to ignite the gases which escape from the fresh coal just after firing.

The grate should be shaken lightly, if at all, most of the clearing of the grate being done with a poker at the time of starting a fire; and it should be dumped only when the accumulation of clinkers is such as to make it necessary, and then it should be re-covered at once with a bed of ashes. For the reason explained on page 11 it is important that the space above and below the oven should be cleaned frequently to avoid the accumulation of soot and ashes.

When the range is fired in this way the excess of air admitted to the fire is probably not more than is necessary; most of the volatile matter in the coal is effectively burned; the combustion of the fixed carbon is practically complete; very little unburned coal gets through the grate into the ash box; and the amount of coal used is, therefore, as small as it could be to accomplish the desired result. On the other hand, when the coal is burned on a grate practically free from ashes, as it often is, and perhaps with holes burned through the fire leaving the bare grate exposed, three or four times too much air passes through the fire box; the temperature of the burning coal and gases may be much reduced and the combustion incomplete, resulting in much smoke and soot; and although, if there are no holes in the fire-bed, the fire may be a roaring hot fire, in any case two or three times as much coal is burned as is necessary.

Fuels Other than Coal for Cooking

The burning of coal in the kitchen range for cooking purposes alone is a very wasteful operation; for, in the first place, usually only a small part of the heating surface of the top of the range and of the oven is utilized, and in the second place a considerable fraction of the coal is burned either before the cooking is begun or after it is finished. Tests made at the State College of Washington indicate that the **average cooking efficiency** of the kitchen range is between 2% and 3%. Hence, not only at the present time because of the needs of the war situation, should fuels other than coal be used for cooking, but also at any other time, particularly if they may be used more efficiently.

Either cord wood or mill wood suitable for the kitchen range is available at present in many localities in the state. As a war measure, the complete substitution of wood for coal in such localities is urged, unless some other more suitable substitute is to be had. At any other time, the use of wood for light, quick fires, and of coal only where a heavy fire is needed for a considerable length of time will probably be found to be more economical than the exclusive use of either one alone, and, at least during the summer months, much more desirable.

Kerosene is an excellent substitute for coal. The newer stoves for burning it, have a cooking efficiency of about 25%; are more economical than the coal range; and, except for the slightly disagreeable odor which accompanies their use, they are very satisfactory for domestic cooking.

Electricity is not a substitute for coal; it is the ideal fuel for cooking. Its use is not accompanied by the many inconveniences which attend the use of the other fuels. The modern electric range is the most efficient cooking equipment available; and, if a suitable size is selected for a given family, it meets every requirement of domestic cooking. Here in the Northwest, where there is available an almost unlimited amount of water power for generating electric energy, its use for domestic cooking cannot be too strongly urged, not only as a means of saving coal to meet the present war emergency but also as a means of conserving the supply of coal and other fuels in time of peace.

OTHER USEFUL BULLETINS

1. The Economical Purchase and Use of Coal for Heating Homes with Special Reference to Conditions in Illinois. 1917. Engineering Experiment Station. Circular No. 4. Urbana, Illinois. Price 10 cents.
2. Saving Fuel in Heating a Home. U. S. Bureau of Mines. Technical Paper 97. 1915
3. Fuel Tests with House-Heating Boilers. University of Illinois Engineering Experiment Station. Bulletin No. 31. Urbana, Illinois. 1909.
4. House Heating Fuel Tests. Iowa State College Engineering Experiment Station. Bulletin No. 33. Ames, Iowa, 1913.
5. United States Bureau of Mines. Bulletin No. 22.

EXTENSION SERVICE BULLETINS

by

COLLEGE OF MECHANIC ARTS AND ENGINEERING

1. How to Measure Water. 1915.
2. Sewage Disposal for Country Homes. 1916.
3. Water Supply for the Home. 1916.
4. Cost of Pumping for Irrigation. 1916.
5. Construction and Maintenance of Earth Roads. 1916.

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