July 8, 1958 M. L. JOHNSON 2,841,982

COMPENSATING FUEL DEMAND METER

Filed Dec. 23, 1955

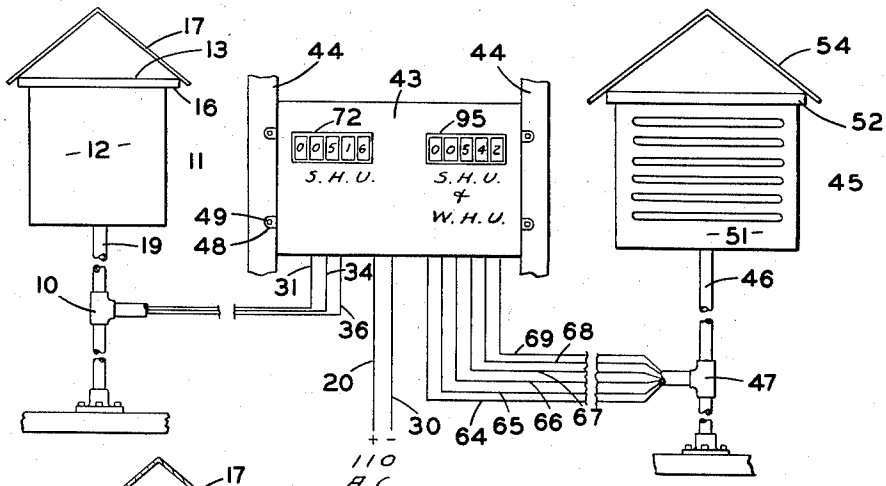


fig. 1

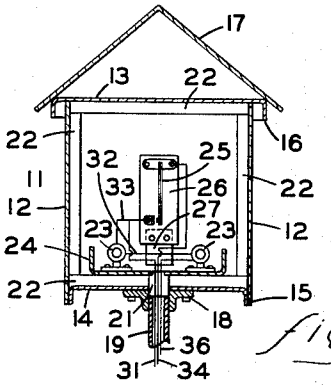


fig. 2

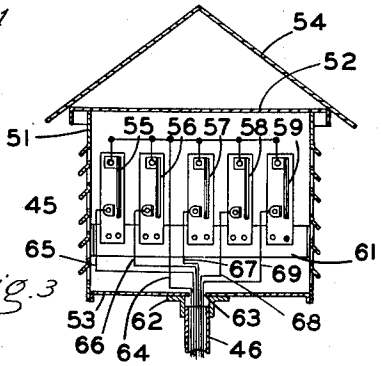


fig. 3

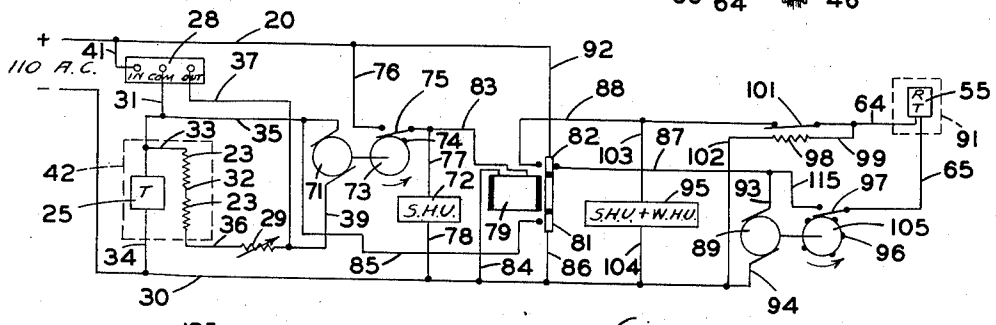


fig. 4

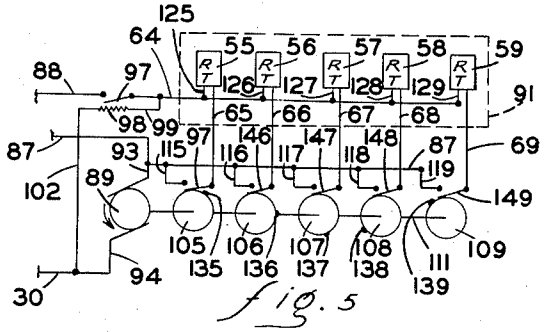


fig. 5

INVENTOR.
MENSAL LEE JOHNSON
BY Lindley E. Mills

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COMPENSATING FUEL DEMAND METER

Mensal Lee Johnson, Kalamazoo, Mich.; Margaret O. Lamb, executrix of the estate of said Johnson, deceased, assignor to Margaret O. Lamb

Application December 23, 1955, Serial No. 554,992

13 Claims. (Cl. 73—339)

This invention relates to a method and apparatus for estimating fuel oil consumption for a building, particularly to a method and apparatus for compensating an estimate, based on space heating requirements alone, for additional oil used for heating water when oil for the two purposes is drawn from a common supply tank. This application is a continuation-in-part of application Serial No. 481,137 filed January 11, 1955.

It is common practice in the heating of residences with oil for each residence to have an oil supply tank which is of a size such that it will hold only a relatively small proportion of a year's consumption of oil. Generally speaking, in the colder months of the year the tank must be refilled every month or two. In the warmer months when little or no oil is used for space heating it, of course, requires filling much less frequently. It is also common practice in the trade for oil to be supplied to residences on a "keep filled" basis whereby the dealer assumes the responsibility for delivering additional oil to the consumer's tank before it is completely empty and before the householder suffers the consequences which would result from an empty tank, such as discomfort, frozen water pipes and other inconveniences and actual damages. It is imperative from the dealer's standpoint not only that the user not be allowed to run out of oil but, also, that he make deliveries to a customer's tank only when the tank is as nearly empty as possible. If this is not done, the cost to the dealer of his delivery service is excessively high and may mean the difference between a profit and a loss. Any such unnecessary delivery cost must, of course, be reflected in the price of oil to the householder.

Most dealers make a practice of estimating the amount of oil consumed by each of their customers so that they will have a general idea of when each customer's tank should be refilled. One method of estimating such requirements is based upon daily temperature readings, made either by the dealer at his headquarters or obtained from an official source, such as the Weather Bureau. Using this system of estimating, it is essential that the temperature be noted at several specified times during each twenty-four hour period and averaged. The data is generally recorded as the number of "degree-days" accruing below a fixed reference temperature, usually 65° F. Thus, if the average of four temperature readings taken at six hour intervals during a particular twenty-four hour period is 45° F., the recording for that day is twenty degree-days. The degree-days are accumulated from day to day and when a specified number of such units have accumulated following the filling of the householder's fuel supply tank it is estimated that the tank should be refilled. The number of degree-days which can be allowed to accumulate between successive fillings of each customer's tank is also dependent upon a factor which takes into account the size of the residence, the style of construction, the degree of insulation and the heating habits of the occupants. By relating the oil used between successive fillings to the degree-days accumulated during the same period, it is possible to work

out a more or less constant factor for each particular dwelling which can be expressed as the number of gallons of oil consumed per degree-day below the reference temperature for that particular residence. Using this factor, it is possible to estimate more accurately the delivery requirements for each specific residence.

It is apparent that this method, which is based on spot temperature observations and which fails to take into account the effect of wind velocity, the amount of sunshine and rain and other atmospheric variables, involves considerable calculation and is, at best, only a rough approximation. Most dealers employing such estimating methods regularly plan on refilling their customers' tanks when their estimates indicate that the tank is about 65 percent empty, because it has been found that if any greater reliance is placed upon such estimating procedures there is great danger of a considerable proportion of the customers running entirely out of oil before a delivery is made. It is apparent that if deliveries could be spaced so that a more nearly complete tankful of oil could be delivered each time, the delivery cost would be decreased proportionately. At the same time any method for estimating fuel requirements for a residence should be sufficiently accurate to insure that delivery is made before the customer's tank is empty.

There has been described and claimed in the parent application a method and apparatus for integrating the heat-absorbing capacity of the atmosphere whereby the fuel dealer who is operating on a keep-filled basis can estimate automatically the space heating fuel requirements of each of his customers with a great deal more accuracy and safety, and with much less laborious computation, than is possible using the method based on spot temperature observation just described. According to the method of the parent application, the integration is carried out in such a way that, in addition to temperature, atmospheric conditions, such as humidity, wind velocity, rain and sunshine, which affect its heat-absorbing capacity, are taken into account, the result being recorded by the apparatus in terms of any convenient unit. Such a unit can be referred to as a "space heating unit." The apparatus for recording such units is operated at some convenient location, usually at the dealer's headquarters, under weather conditions representative of the region serviced by the dealer.

By noting the amount of oil consumed for space heating at a particular residence between successive initial test fillings of the tank and the number of space heating units accumulated by the integrating apparatus during the same period, a factor can be obtained for the residence involved in terms of gallons of oil consumed per space heating unit recorded. This factor, conveniently referred to as a "space heating factor" is remarkably constant for any particular residence when determined at different periods of the year using the apparatus of the parent application. From the information thus available, it is a simple matter to determine the number of space heating units that can be allowed to accumulate safely on the integrating apparatus for any residence between successive fillings of the supply tank for the residence. This is, of course, also true for buildings other than residences where a relatively even degree of heating is maintained.

Although the method and apparatus of the parent application are highly effective in taking into account all weather conditions and in estimating fuel oil requirements for heating a building, it is to be noted that the estimates obtained refer only to fuel required for space heating and do not take into account fuel utilized for other purposes. Many residential users of fuel oil for space heating also utilize oil from the heater supply tank for heating water to be used in the residence and it is apparent that any estimate based entirely on space heating requirements

will be inaccurate to an extent which depends upon the proportion of the total oil consumed which is used for heating water. Accordingly, it is essential, for economy on the part of the dealer and for safety on the part of the householder, that such additional uses of oil be taken into account when estimating needs for residences where oil from the same supply tank is used both for space heating and for heating water. If this is not done, the estimate will be highly inaccurate and the advantages of the estimation will be largely nullified. Thus, an estimate based on oil requirements for space heating alone will, in moderately warm or summer months, be much less than the actual oil consumed since little or no oil may be utilized for space heating whereas considerable oil may be used for heating water. If the dealer relies on an estimate based on space heating requirements alone, it is highly probable that his customer's supply tank will become empty during the summer or during periods of mild weather. The same situation exists during the cold months although the likelihood of the householder's supply tank becoming completely empty is not so great as it is in the summertime because the actual proportion of total oil used during the cold months for heating water is relatively low and is generally well within the limit of safety practiced by a responsible dealer. On the other hand, it is desirable that even this chance for error be eliminated and that the dealer have available at all times a reliable method and apparatus for estimating his customer's oil needs during both cold and warm weather regardless of whether oil is used both for heating water and for space heating or only for space heating.

Many dealers make it a practice, in instances where oil is used for heating water, to add an arbitrary correction factor per unit of time to the customer's estimated requirements of oil for space heating regardless of how the estimate is made. When the estimate for space heating is calculated from data obtained as degree-days by temperature observations, the usual method of correction is to add a certain number of degree-days per day to the degree-day value obtained from temperature observations. The actual value of the correction added varies from dealer to dealer and from residence to residence because, using space heating unit determinations as heretofore practiced it has not been possible to arrive at a suitable value of the correction which could be used by all dealers or even by one dealer for all residences serviced by him. The addition of an arbitrary correction factor which varies relatively constantly with time and to a considerable extent for each residence, and which is relatively independent of weather conditions, to an estimated value which is relatively independent of time, and which is dependent principally upon weather conditions, presents difficulties and at best requires a continuous checking of each account by the dealer to be sure that his deliveries are spaced for the greatest economy to himself and with no likelihood of the customer's tank becoming empty. The chances for error in such a procedure are great.

The present invention relates to a method and apparatus whereby the estimate of the amount of oil consumed for heating a building as obtained by the method and apparatus of the parent application can be compensated or corrected automatically to provide a reliable estimate for the amount of oil consumed in buildings where oil is used for heating water, or for other relatively time-dependent, weather-independent purposes, in addition to its use for space heating. The method and apparatus of the present invention are based on certain empirical relationships which have been discovered to prevail when oil is used both for space heating and for heating water. For a better understanding of the invention, the nature and value of these relationships will be described in some detail.

It has been found empirically that, in a group of residences in any particular locality of relatively uniform climatic conditions employing oil both for space heating and for heating water, the proportion of the total oil required during a year's period which is used for heating water has a fairly constant value. This proportion will, of course, vary somewhat from residence to residence within a given community, but not to a degree which might at first be imagined. The compensation of the estimated yearly fuel demand for space heating as obtained by the method and apparatus of the parent application by such a common factor brings the compensated estimate into close agreement with actual consumption for residences of different sizes and heating habits of the occupants. The compensating proportionality factor applicable for this purpose will, of course, vary with respect to climate, being higher in warmer climates and lower in colder climates. Under the climatic conditions prevailing in southern Michigan, for example, it has been found that a compensating factor, obtained as described, of 25 percent of the total oil consumed during a period of one year, or one-third of the amount used for space heating alone, can be used in most instances. The invention will, therefore, be described with respect to a compensating factor of 25 percent of the total oil consumption in the climatic region mentioned, but it is to be understood that any other factor applicable under other climatic conditions can be employed in like manner.

It is to be noted that the empirical factor of 25 percent for the climatic region mentioned is based on the total oil consumption in residences of different sizes and with different numbers of persons living in them and, furthermore, that it refers to the yearly consumption of fuel. It appears that the relatively constant nature of this proportion results from a number of factors. One factor is that the rate of consumption of hot water in any particular household, and therefore of oil required to heat the water, is relatively constant throughout the year. It is apparent that most of the factors which affect the rate of oil consumption for space heating, such as atmospheric temperature, wind velocity, sunshine and rain, type of construction and degree of insulation of the building, and the like, have little effect on the rate of consumption of oil for heating water. The rate of oil consumption for space heating is, of course, not constant and, in most climates, varies from little or none used during the warmest months to a maximum rate during the coldest months.

Another factor is that, generally speaking, the larger the residence concerned the greater the number of individuals that occupy the residence and, therefore, the greater the amount of hot water that is used. In other words, it appears that, in general, there is a fair correlation between the size of a residence and the amount of hot water used in the residence. It should be understood, of course, that the factors mentioned are not precise and that the proportion of 25 percent referred to may actually vary by as much as 30 percent in either direction, depending, in part, upon the numbers and habits of individuals residing in a particular dwelling, it has been found by observation that it is the exceptional residence in the climatic region referred to which utilizes oil for both space heating and water heating that will use less than 17 to 18 percent or more than 32 to 33 percent of the total oil consumed over a yearly period for heating water. The actual proportion for any particular residence can, when necessary, be arrived at with considerable accuracy by observing the monthly consumption of oil during the summer months when no oil is used for space heating and then calculating the yearly consumption at the same rate. This value, together with the total yearly oil consumption of the residence, can then be used to calculate the proportions for that residence of the yearly oil consumption used for effecting space heating and for heating water.

It has also been found, empirically, that when factors corresponding to the space heating factors for each of a group of residences using oil both for space heating and for water heating are determined during cold months

when a relatively low proportion of the total oil used is consumed for heating water, and on the basis of total oil used during the period rather than upon that used for space heating alone, a compensated factor is obtained the use of which offsets to a considerable degree the inaccuracies in cold weather otherwise encountered when estimates based on space heating requirements alone are corrected for each of the residences involved by the addition of the same amount of oil per unit of time to each estimated requirement. This compensated factor can, for convenience, be referred to simply as the "residence factor," it being apparent that, in the case of a residence using oil for space heating alone, the "residence factor" becomes the "space heating factor" and that the term "residence factor" can be used in either case in relating to total oil requirements whether or not water heating is involved.

It has now been found that the residence factor described and the relatively constant proportion which has been found to prevail in residences throughout a region of similar climatic conditions between the total yearly amount of oil used and that used for water heating can be employed in obtaining a highly reliable estimate of the fuel requirements of the individual residences within the region in which oil is used both for space heating and for water heating. It is, of course, not possible to add arbitrarily a factor of one-third the estimated oil consumption for space heating of any particular residence unless the supply tank for the residence is large enough to hold an entire year's supply of oil. Such an arbitrary addition on a percentage basis would, for the usual small tank, indicate that the tank needed refilling in cold months when it was only 60 to 70 percent empty and would fail entirely to account for the use of oil for heating water during warm months.

When the residence supply tank which is to be kept filled by the dealer does not hold a year's supply of oil, the compensating amount must be based not only upon the constant proportion of total yearly oil requirements of the residence but must also take into account the relatively uniform rate of oil consumption for water heating throughout the year, as contrasted to the widely fluctuating rate required for space heating. Furthermore, for most accurate results, the determination of the compensating amount must, since it is based on the empirical proportionality found, provide for the variation of the actual value of the proportion inversely as the rate of total oil requirement varies. In other words, the compensating proportion should be low in cold months when the rate of oil consumption for space heating is high and should be proportionately higher during mild and warm months when the rate of oil consumption for space heating is low or nonexistent.

According to the present invention, the method and apparatus of the parent application are employed at a central location to record space heating units (S. H. U.) based on weather condition. The units accumulated by the apparatus over a particular period of time during cold weather are utilized in conjunction with the actual oil consumed in each of a group of residences during the same period of time to calculate a residence factor for each of the residences concerned, regardless of whether or not oil is used for heating water in the several residences. Based on this factor and the accumulated units recorded by the apparatus over ensuing periods of time, the oil consumption in those residences utilizing oil for space heating only can be estimated directly as set forth in the parent application. In the case of residences where oil is also used for heating water, the space heating units and, consequently, the residence factor and the estimated oil consumption are compensated on a percentage basis corresponding to the proportion of total oil used for water heating during the cold period when the residence factor was obtained.

In the case of a residence using oil for heating water in addition to space heating, a further compensation or correction, which may be constant with respect to time at higher temperatures but which is preferably varied with respect to temperature and time at lower temperatures in a manner which will be explained, is made. It has been found, empirically, that when the units recorded by the apparatus and the added time-dependent correction are each expressed in terms of degree-days, as determined in corrected form by the apparatus of the parent application, the value of five degree-days per day can be added each day during warm and very mild days with good results. It is to be noted that by employing the residence factor based on total oil consumption during a cold period and by using a value for the added correction in terms of units based on comprehensive weather observations as determined by the apparatus of the parent application, it becomes possible to add the same correction for substantially all residences in the region without serious error. The apparatus of the present invention provides means for adding automatically such a correction to avoid the inconvenience and attendant likelihood of error when adding such a correction at regular intervals by calculation. Thus, only one apparatus, which can be operated at a convenient central location, need be utilized and, at the same time, the use of a different correction for each residence is avoided.

It will be noted that the method just described leads to a much closer approximation than estimates obtained by previously known methods because a part of the oil utilized for water heating is accounted for in the residence factor employed. This reduces the likelihood of error in the estimate during cold periods and minimizes the significance of an error in the estimation during mild and warm periods when the total rate of oil consumption is low. The degree of accuracy of the approximation in mild and warm periods is dependent in large measure upon the relationship between the rate at which water heating units (W. H. U.) are accumulated by the apparatus as a result of weather conditions and the compensation included in the residence factor and the rate at which essentially time-dependent water heating units are accumulated.

It has been noted previously that under the climatic conditions referred to the proportion of total oil consumed in any individual residence over the period of one year which is used for heating water is approximately 25 percent. This means that on any day during the year on which the number of units accumulated by the apparatus, exclusive of the constantly added time-dependent water heating units, is $\frac{1}{365}$ of the total yearly accumulation of such units, the added time-dependent units should be 25 percent of the total units accumulated for the day. If both units are expressed, as is convenient, in terms of degree-days, the total number of degree-days accumulated on such a day will be 20, of which 5 units will be added time-dependent units. Therefore, for closest approximation, employing a reference temperature of 65° F., the apparatus is calibrated so that the ratio of added time-dependent units to total accumulated units is 1 to 4 when the average temperature for the day is 50° F., regardless of the nature or size of the units employed. In practice, it is convenient to construct and calibrate the apparatus so that it will register a maximum of 100 units or degree-days in each twenty-four hour period, corresponding to a zero temperature of −35° F., and to then add in 5 such units per day as the constant correction. Such addition is made continuously at atmospheric temperatures above about 50° F., often continuously above about 45° F. as a matter of precaution. According to one modification of the process, the addition of time-dependent water heating units is discontinued entirely below 45° to 50° F. although this need not necessarily be done, as will now be explained.

It will be noted that when the method is carried out as thus far described the estimate obtained is of least accuracy when units are recorded by the apparatus at an atmospheric temperature just below the temperature at which the addition of time-dependent units is discontinued. Under such conditions the accumulation of units by the apparatus to compensate for the use of oil in heating water is on a percentage basis of the total accumulated units. The error introduced by discontinuing the addition of time-dependent units becomes smaller and eventually disappears substantially entirely when the low temperature at which the residence factor was determined is reached. Generally speaking, the error involved is not serious since at the temperatures concerned oil is used for heating at a fairly rapid rate and the accumulated error between successive fillings of the supply tanks is not great in terms of actual gallons of oil.

However, certain variations of the process and apparatus allow for the reduction of even this small margin of error. This is effected by decreasing the rate of addition of time-dependent water heating units gradually as the atmospheric temperature decreases. An abrupt discontinuation of the addition of the time-dependent units is thus avoided. In the ways described the agreement between the estimated oil consumption for each of a number of residences within a uniform climatic region and the actual oil consumption of the individual residences is increased to a point such that deliveries of oil by the dealer on a keep-filled basis to the supply tanks at each of the residences can be effected with entire safety and with a high degree of economy regardless of whether oil is used for space heating alone or for both space heating and water heating.

The invention can be understood readily by reference to the accompanying drawing wherein, in the interest of clarity, certain features are shown on a somewhat exaggerated scale and wherein

Figure 1 is a schematic elevation, partially broken away, illustrating external features of the apparatus of the invention;

Figure 2 is a vertical sectional elevation of a reference chamber of Figure 1 showing an arrangement of certain elements of the apparatus therein;

Figure 3 is a vertical sectional elevation of an outdoor thermostat housing of Figure 1 showing an arrangement of certain elements of the apparatus therein:

Figure 4 is a schematic diagram of one modification of an electrical system of the apparatus of the invention; and

Figure 5 is a schematic diagram of a different modification of a part of the electrical system of Figure 4.

Referring to Figure 1, there is shown schematically the principal external features of the apparatus. These include a reference chamber, shown generally at **11**, which is mounted in suitable fashion out of doors and which contains certain elements of the apparatus, as will be described later, and a thermostat housing, shown generally at **45**, which may be a conventional louvered weather observation station and which contains certain elements of the apparatus and is suitably mounted out of doors, as will also be explained later. The apparatus also conveniently includes a suitable case, shown generally at **43**, which can contain certain elements of the apparatus and which is mounted, e. g. by bolts **49** securing lugs **48** on the side of the case to suitable supporting members **44**, at any convenient location, usually indoors. The electrical elements of the apparatus can be operated by ordinary 110 volt alternating current available through the conductors **20** and **30**. The elements of the electrical system of the invention contained in the reference chamber **11**, the thermostat housing **45** and the case **43** are connected in suitable fashion, as will be explained in detail, by conductors as illustrated schematically in Figure 1. The lengths of the various conductors depend, of course, upon the locations with reference to one another of the reference chamber **11**, the thermostat housing **45** and the case **43**.

The reference chamber **11**, shown in detail in Figure 2, comprises comveniently a boxlike structure having outer side walls **12**, a cover **13** and a bottom **14**, preferably constructed of material having a high radiation factor or emissivity, e. g. 0.75 or above. The chamber, which is mounted out of doors, is constructed of weatherproof material and is fabricated so as to be leakproof, e. g. by having the cover, bottom and sidewall members constructed of suitable light guage metal welded to one another in watertight fashion. The chamber is preferably constructed with the sidewalls **12** extending below the bottom **14**, as at **15**, to facilitate draining of rain water cleanly from the sides and with an overhanging edge of the cover **13**, as at **16**, to eliminate any possibility of leakage of rain water into the chamber along the tops of the sidewalls **12**. It is advisable, to avoid accumulation of ice and snow on the cover **13** of the chamber, to provide a canopy **17** over the cover. One convenient form of canopy comprises a sheet of aluminum bent to form a roof-shaped piece and secured along opposite edges of the cover **13**, the other sides of the enclosure between the canopy and the cover thus being open. Such a canopy generally projects on all sides beyond the sidewalls of the chamber.

The reference chamber **11** is mounted several feet above the ground in the open, or above a building, where it will not be shaded or subjected to undue heat radiation from nearby objects. In the illustration given in Figure 2, the bottom 14 of the chamber **11** is secured to a conventional pipe flange **18** into which is screwed a pipe **19** of suitable length and diameter, the pipe being secured at its other end in a suitable location, thus forming a mast on the top of which the chamber is mounted. A hole **21** is formed in the bottom **14** of the chamber in register with the opening through the flange **18** to provide for entry of electrical conductors into the chamber by way of the pipe mast. A suitable pipe T **10** is conveniently inserted between sections of the mast **19** through which the electrical conductors can be led from the interior of the mast to a convenient central location, conveniently the case **43** of Figure 1.

The interior of the chamber **11** is lined with a carefully fitted layer of insulation **22** to reduce the rate of heat flow through the chamber wall. A variety of insulating materials can be employed although, for best results, a material having as low a rate of heat transfer coefficient with respect to temperature as possible is preferred, as will be apparent later. A good grade of wood fiber insulating board is satisfactory for most purposes. The amount of insulation employed can be varied over reasonably wide limits, although when too great a degree of insulation is employed the rate of heat transfer through the wall may be so slow as to render the instrument somewhat inaccurate because of its lack of sensing frequent small changes in the atmosphere. On the other hand, if not enough insulation is employed, the instrument may be too sensitive to changes in the atmosphere for best results. Good results are generally obtained when the wall is constructed to have an absolute rate of heat conduction through it of from about 5 to about 0.05 B. t. u./sq. ft./hr. for each degree Fahrenheit temperature differential through the wall. Generally speaking, a ½ inch layer of wood fiber board having a heat transfer value of about 0.33 B. t. u./sq. ft./inch/° F./hr. has been found suitable as an insulation lining for use in most instances, although the invention is not limited in this respect.

The insulated reference chamber **11** is equipped with a thermostatically controlled heating unit inside it whereby the temperature of its interior can be maintained at a practically constant value higher than that of the atmosphere surrounding the chamber. In the modification shown, a pair of conventional electrical resistance heaters

23 are mounted within the chamber and shielded with a suitable shield 24 to minimize direct radiation from the heaters to the wall surfaces. A suitable thermostat 25 is mounted, e. g. on a panel 26 on a panel-supporting bracket 27 near the center of the chamber, and the heaters and thermostat are connected to a suitable source of E. M. F., e. g. 110 volt A. C., as shown in more detail in Figure 4. In most instances the heating unit and thermostat can be conected in series because, as usually constructed and operated, the chamber requires the utilization of only a low amperage current to energize the heating unit. However, it is apparent that in instances where it may be more desirable the heating units can be energized in response to the thermostat through a relay in conventional manner without altering the scope of the invention.

The thermostat housing 45 of Figure 1, which is shown more in detail in Figure 3, consists of any suitable enclosure in which one or more thermostats can be mounted for measuring atmospheric temperature. One convenient form of housing comprises a conventional weather observing station cabinet having louvered sidewalls 51, a cover 52 and a bottom 53. A canopy 54, similar to the canopy 17 of Figures 1 and 2, can be provided to prevent the accumulation of ice and snow on the cover 52 of the housing and to minimize the radiant effect of direct sunlight on the cover. The housing 45 is preferably constructed so that rain cannot enter into the housing but, because of the louvered sides, is open to free circulation of the atmosphere through it.

The housing is mounted out of doors several feet above the ground where it is subject to free circulation of the air. One convenient form of mast includes a standard pipe flange 62 secured to the bottom 53 of the chamber in register with a port 63 in the bottom through which electrical conductors can be led from the housing into the interior of the mast. A pipe 46 is screwed into the flange 62 and is secured at its lower end in suitable fashion in the ground or to a supporting member, thus forming a mast on which the housing is mounted. A pipe T 47 is preferably inserted between sections of the mast 46 by means of which electrical conductors can be led out of the mast to a suitable location.

The thermostat housing 45 is equipped with one or more reverse acting thermostats (RT) so that the thermostats can each be employed to form a circuit at higher temperatures and to interrupt the circuit at lower temperatures. In the modification shown in Figure 3, a series of five thermostats 55, 56, 57, 58 and 59 are employed, each mounted on a suitable panel with the panels secured to a suitable support 61 within the housing.

One terminal of each reverse-acting thermostat mounted in the thermostat housing is connected to a common conductor 64. The other terminals of the thermostats 55, 56, 57, 58 and 59 are connected to conductors 65, 66, 67, 68 and 69, respectively. The conductors 64, 65, 66, 67, 68 and 69 are led out of the thermostat housing, e. g. through the mast 46, to a convenient central location, conveniently the case 43 of Figure 1. It is to be noted that whereas the interior of the reference chamber 11 is maintained at a substantially constant temperature by the heaters 23 in response to the control of the thermostat 25, the temperature inside the thermostat housing 45 varies freely according to atmospheric temperature and the thermostats in the housing merely control the flow of current in separate circuits of which each is a part according to the setting of the different thermostats. Furthermore, since the thermostats in the thermostat housing are reverse acting, they can be set so that at a high temperature currents flow through each of them but so that as the temperature in the housing falls the terminals of the thermostats will separate at different temperatures and the currents flowing in the thermostat circuits will be interrupted in successive fashion. If desired, the thermostats can be set so that at a suitably low temperature

current does not flow through any of the thermostat circuits. The purpose of this arrangement will be explained later.

In Figure 4 there is illustrated schematically a preferred form of the electrical circuits employed when utilizing a single thermostat 55 in the thermostat housing, represented schematically in dotted outline at 91, the thermostat being connected into the rest of the circuit through the conductors 64 and 65. The circuit is energized from a convenient source of E. M. F., e. g. 110–120 volts A. C., through suitable conductors 20 and 30. The input pole of a constant voltage regulator 28 is connected to the conductor 20 by a conductor 41. The common pole of the constant voltage regulator 28 is connected through a conductor 31 to one terminal of the thermostat 25, the other terminal of which is in turn connected through a conductor 34 to the conductor 30. The primary of the constant voltage regulator and the thermostat are thus in series across the E. M. F. source. When the terminals of the thermostat are in contact, the primary of the constant voltage regulator is energized and a constant voltage secondary current is available through the output and the common poles of the regulator.

A variable resistance 29 and the heating units of 23 are connected in series by the conductors 33, 32, 36 and 37 between the output pole and the common pole of the constant voltage regulator 28. A synchronous motor 71 is also connected across the constant voltage terminals of the regulator 28 by means of conductors 35 and 39 in parallel with the heaters 23 and the variable resistance 29. When the primary circuit of the voltage regulator is closed by the thermostat 25, the heaters 23 are energized and the synchronous motor 71 operates at constant speed. The rate of heat generation of the heaters 23 can be regulated by adjustment of the adjustable resistance 29. The adjustable resistance 29 is, of course, held constant after its initial adjustment. Because of the fact that the heaters 23 are energized by a constant voltage current, their heat output per unit time of energization is constant and bears a direct relationship to the number of revolutions of the synchronous motor 71. Furthermore, the total time of energization of the heaters 23 during any given period of time is a measure of the integrated heat absorbing capacity of the atmosphere surrounding the reference chamber for the same period of time.

The synchronous motor 71 is utilized to form and interrupt a circuit across the main power supply which in turn actuates an impulse counter 72, sometimes herein referred to as a "second" impulse counter to differentiate it from a "first" impulse counter 95 which will be referred to later. In the modification shown, the motor 71 rotates a cam wheel 73 having on its peripheral surface a cam riser 74 which closes a switch 75 each time the cam wheel rotates. The switch 75 and the impulse counter 72 are connected in series by way of the conductors 76, 83, 77 and 78 between the conductors 20 and 30. The counter 72 thus registers one unit each time the switch 75 closes, the number of units thus accumulated within a given time interval being a direct measurement of the heat-absorbing capacity of the atmosphere surrounding the reference chamber integrated over the interval involved. The magnitude of each unit depends upon the setting of the thermostat 25 and of the adjustable resistance 29 and upon the speed of rotation of the cam wheel 73 and the number of cam risers 74 on its periphery. The thermostat 25 and the heaters 23 are located inside the reference chamber shown in dotted outline at 42 in Figure 4, the other elements of the electrical system being located elsewhere.

Prior to installation the apparatus is standardized by placing the reference chamber in a suitable standardizing chamber where the temperature, humidity, convection currents and other factors which affect the rate of heat absorption by the atmosphere through the walls of the reference chamber are kept as nearly constant as pos-

sible. The thermostat 25 is set to open and close at a suitable reference temperature, usually 65° F., and the temperature of the standardizing chamber is kept constant at a temperature lower than that of the reference chamber. The device is then operated over a period of time and the reading accumulated by the counter 72 is noted. Since the accumulated reading of the counter is a linear function of the time of operation of the motor 71 and the latter is essentially a linear function of the difference between the reference temperature within the reference chamber and the temperature of the standardizing chamber, it is possible to calculate easily the temperature at which the standardizing chamber would have to be maintained for the heating elements 23 to operate continuously during the total elapsed time to maintain the reference temperature constant. This temperature is herein referred to as the "zero" temperature of the standardizing chamber and represents the lowest temperature of an otherwise constant atmosphere in which the apparatus can be operated satisfactorily without readjusting the adjustable resistance 29 to decrease its resistance value and thus to increase the rate of heat generation by the heaters 23. It is apparent also that the motor 71 will not operate and that the reading of the counter 72 will not increase when the temperature inside the reference chamber is higher than the reference temperature.

In practice it is convenient to regulate the rotational speed of the cam riser, e. g. by suitable gearing, and to provide a suitable number of cam risers on its periphery to cause the switch 75 to close at the rate of 100 times for each 24 hours of continuous operation of the motor 71 and also to regulate the auxiliary resistance 29 to establish a zero temperature 100° below the reference temperature, i. e. at −35° F. when the reference temperature is 65° F. With the apparatus constructed and adjusted in this way, the space heating units registered on the counter 72 are directly in integrated degree-days of the test chamber below the reference temperature for the test period. By subsequent exposure of the reference chamber to an atmosphere variable as to temperature and also as to other factors affecting its heat-absorbing capacity, the heat-absorbing capacity of the variable atmosphere is integrated and recorded as an equivalent number of degree-days. Space heating units other than degree-days can, of course, be employed, if desired. Space heating units as thus recorded on the impulse counter 72 over a period of time can be employed directly, together with the residence factor for a building where oil is not utilized for heating water, to estimate accurately the oil consumption for the building.

Certain additional features are also included in the electrical circuit in order to compensate the accumulated reading of the counter 72 for instances where oil is used for heating water as well as for space heating. Thus, in the modification shown in Figure 4, a solenoid 79 is provided which actuates a single throw switch 81 and a double throw switch 82. The solenoid 79 is connected across the power supply between the conductors 20 and 30 in series with the switch 75 by means of the conductors 76, 83 and 84. The solenoid 79 is thus energized during the time the switch 75 is closed in response to the action of the cam riser 74. The purpose of the switch 81, which is connected in parallel with the thermostat 25 between the common pole of the voltage regulator 28 and the power supply conductor 30 by conductors 85 and 86, is to insure the continued operation of the synchronous motor 71 until the switch 75 opens should the thermostat 25 interrupt the current through the primary circuit of the voltage regulator while the switch 75 is still closed. Due to the shunt circuit around the thermostat 25, the voltage regulator secondary circuit remains energized and the motor 71 continues to operate until the switch 75 is released from the cam riser 74 and permitted to open. The solenoid 79 is then no longer energized and the switch 81 opens and remains open until the thermostat 25 again closes and the motor 71 brings the cam riser 74 into position to again close the switch 75.

The double-throw switch 82 is normally closed with respect to the conductor 87 when the solenoid 79 is not energized and thus normally closes a circuit from the main power conductor 20 through the conductor 92 to the armature of the switch 82 and to the conductor 87. Energizing of the solenoid 79 actuates the switch 82, interrupting the flow of current from the conductor 20 to the conductor 87 and closes the switch with respect to the conductor 88. Another, or "first," impulse counter 95 is connected in series with the switch 82 across the main power supply between the conductors 20 and 30 by way of conductors 92, 88, 103 and 104, the circuit being formed each time the switch 75 closes. A space heating unit is thus recorded on the counter 95 each time a space heating unit is recorded on the counter 72. It is seen that the double throw switch 82 actually comprises two switch means, the means for making and interrupting electrical connection between the conductors 86 and 88 sometimes being referred to herein as a "first" switch means to differentiate it from a "second" switch means 97 which will be referred to later.

A second synchronous motor 89 is provided and connected across the main power supply between the conductors 20 and 30 by way of the conductor 92, the switch 82 and conductors 87, 93 and 94, the circuit being formed when the solenoid 79 is not energized. The motor 89 thus runs continuously except for the time during which the solenoid 79 is energized. The motor 89 actuates a cam rotor 105 which, in the modification of Figure 4, has a series of cam risers 96 on its peripheral surface. Each of the cam risers 96 closes a normally open "second" switch means 97. The switch 97 is connected across the main power supply between the conductors 20 and 30 in series with a reverse-acting thermostat 55 in the thermostat housing, represented in dotted outline at 91, a normally closed time-delayed opening switch 101 and the impulse counter 95 by way of the conductor 92, the switch 82 and conductors 87, 115, 65, 64, 88, 103 and 104.

The time-delayed switch 101 is of the normally closed time-delayed automatic opening type which, upon completion of a circuit allowing current to flow through the switch, remains closed for a predetermined length of time and then opens automatically and remains open until the circuit is broken by other means. Although any conventional switch of this type can be used, the particular modification illustrated includes a bimetallic element as the movable switch member with a suitable heating element 98 located closely adjacent to it. The heating element 98 is connected by conductors 99 and 102 between the conductors 64 and 30 so that it becomes energized at the same time that current begins to flow through the switch 101. The reverse-acting thermostat 55 is set to open at a predetermined temperature, usually at 45° or 50° F., so that the circuit through it is interrupted at atmospheric temperatures below this.

With the switch 82 in its normal position in contact with the terminal of the conductor 87 and with the temperature of the reverse-acting thermostat 55 higher than that at which it is set to open and interrupt the circuit, an additional unit is registered on the impulse counter 95 each time the switch 97 is closed by one of the cam risers 96. After a time lag sufficient to insure actuation of the counter, e. g. two to three seconds, the switch 101 opens automatically and the counter 95 is shunted out of the circuit which includes the reverse-acting thermostat 55 and the switch 97. The switch 101 remains open until the cam riser 96 disengages the switch 97 allowing the latter to open and interrupt the flow of current through the heating element 98. The switch 101 closes as soon as the heating element 98 cools and is then

ready for a repetition of the action. The reason for shunting the counter 95 out of the circuit will be apparent later. When the temperature of the atmosphere is below the temperature at which the reverse-acting thermostat 55 is set to open, the closing of the switch 97 does not cause an additional unit to be registered on the counter 95.

The apparatus just described, therefore, causes the registration on the counter 95 of units conveniently referred to as "water heating units" or abbreviated to "W. H. U.," at a regular rate depending upon elapsed time and upon the construction and setting of the mechanism whenever the atmospheric temperature is above the setting temperature of the reverse-acting thermostat 55. These time-dependent units are registered by the counter 95 in addition to the space heating units registered on the same counter in response to the energizing of the solenoid 79. The total of the units registered on the counter 95 is thus the sum of the space heating units registered on the counter 72 and the added time-dependent water heating units just referred to. The frequency with which water heating units are registered on the counter 95 when the circuit is not interrupted by the reverse-acting thermostat 55 is dependent upon the rotational speed of the cam wheel 105 and the number of cam risers 96 on its periphery. With the construction and adjustment of the auxiliary resistance 29 and the cam wheel 73 as described previously, it is convenient to construct and adjust the cam wheel 105 so that it rotates once during each 24 hour period and has five cam risers 96 on its periphery. Under such conditions five water heating units are registered on the counter 95 during each 24 hour period.

The total number of units registered on the counter 95 during a period of cold weather when the open thermostat 55 prevents the registration of time-dependent units can thus be used in conjunction with the amount of oil actually used in a particular residence during the same period for both space heating and water heating to calculate a residence factor for the particular residence concerned which includes a compensation for the amount of oil used during cold periods for heating water.

It is to be noted that whenever the solenoid 79 is energized the conducting path from the conductor 92 through the switch 82 to the conductor 87 is broken and the motor 89 ceases to run momentarily except in rare instances when both of the switches 101 and 97 are closed and the poles of the reverse-acting thermostat 55 are in contact. Even under such circumstances the formation of the new circuit through the conductor 92, the switch 82 and the conductors 88, 103 and 104 and the impulse counter 95 between the conductors 20 and 30 will, because the flow of current to the counter 95 is first broken momentarily, furnish a new impulse to the counter and a space heating unit will be recorded on it. The period of energizing of the solenoid is longer than the time-delay period of the switch 101 so that when the solenoid becomes deenergized the switch 101 will have opened and the reforming of the circuit between the conductors 92 and 87 by the switch 82 does not cause the counter 95 to register a superfluous unit. Under all other circumstances the motor 89 will not run during the time the solenoid 79 is energized. However, with the apparatus constructed and adjusted as previously described, each period of energizing of the solenoid 79, although, as just noted, longer than the time-delay period of the switch 101, is short and is generally of ten seconds or less duration. Furthermore, the frequency of energizing of the solenoid 79 is at a maximum during the coldest weather when the reverse-acting thermostat 55 remains open and becomes very much less than this in warmer weather, being, of course, reduced to zero frequency at atmospheric temperatures above the reference temperature of the thermostat 25. Under such circumstances, the error introduced in the number of added water heating units registered on the counter 95 by the intermittent stopping of the motor 89 for such short periods becomes insignificant.

In the modification shown in Figure 5, the single reverse-acting thermostat 55 is supplemented with four additional reverse-acting thermostats 56, 57, 58 and 59. The cam wheel 105 is also supplemented with four additional cam wheels 106, 107, 108 and 109, all on a common shaft 111 which is rotated conveniently once in each 24 hour period. In this instance, however, each of the cam wheels 105, 106, 107, 108 and 109 has only a single cam riser 135, 136, 137, 138 and 139, respectively, on its periphery. Each of the cam risers 135, 136, 137, 138 and 139 actuates a switch 97, 146, 147, 148 and 149, respectively, once in each 24 hour period. The switches are each connected by conductors 115, 116, 117, 118 and 119 to the conductor 87 and by the conductors 65, 66, 67, 68 and 69 to one terminal of the reverse-acting thermostats 55, 56, 57, 58 and 59, respectively, mounted in the thermostat housing shown in dotted outline at 91. The other terminals of the reverse-acting thermostats are each connected to the common conductor 64 by the conductors 125, 126, 127, 128 and 129, respectively. The balance of the circuit illustrated in Figure 5, including the conductors 64 and 87, is the same as that illustrated in Figure 4.

Using the electrical system of Figure 5, the five reverse-acting thermostats are set to open and interrupt the respective circuits through them at different temperatures. Thus, it is convenient to set the reverse-acting thermostats 55, 56, 57, 58 and 59 to open at 61° F., 53° F., 45° F., 37° F. and 29° F., respectively. Under such circumstances added water heating units are registered on the counter 95 at the rate of five units in each 24 hour period when the atmospheric temperature is continuously above 61° F. When the temperature is between 61° F. and 53° F., units are registered at the rate of four in each 24 hour period because the reverse-acting thermostat 55 is open and the circuit through it is interrupted. In similar fashion, units are registered on the counter 95 at the rate of three in each 24 hour period when the atmospheric temperature is between 53° F. and 45° F., at the rate of two units in each 24 hour period when the atmospheric temperature is between 45° F. and 37° F. and at the rate of one unit in each 24 hour period when the atmospheric temperature is between 37° F. and 29° F. When the atmospheric temperature is below 29° F., all five of the thermostat circuits are interrupted by the respective reverse-acting thermostats and no added water heating units are registered on the counter 95. Employing the modification of Figure 5 and setting the reverse-acting thermostats as just described, it is apparent that the rate of recording of added water heating units on the counter 95 over any period of time when the atmospheric temperature is between 61° F. and 29° F. varies inversely as a rough integration of the atmospheric temperature with respect to time during the period. It is apparent that the number of reverse-acting thermostats can be increased as desired and that the setting of each can be adjusted to suit local circumstances and climatic conditions to make the integration as accurate as desired. Using the arrangement of multiple reverse-acting thermostats just described, the accuracy of the estimate of fuel consumption over the temperature range of 61° F. to 29° F. is increased considerably for residences employing oil both for space heating and water heating over the estimate obtained using only one reverse-acting thermostat as described in connection with Figure 4.

I claim:

1. In apparatus for estimating the fuel oil consumption of a building using oil both for space heating and for a substantially time-dependent, weather-independent purpose, the combination including: a reference chamber having a heat-conducting wall adapted to have its exterior surface in heat-exchange relationship with the outdoor atmosphere; thermostatically controlled electrical heating means within the reference chamber adapted to

maintain the temperature therein substantially constant at a predetermined value; means outside the reference chamber to supply constant voltage electric current for energizing the heating means; a synchronous motor outside the reference chamber controlled by the same thermostat that controls the heating means whereby the motor is caused to operate during the periods of energizing of the heating means; a first switch means adapted to be opened and closed at regular time intervals in response to operation of the motor during the periods of its operation; a first impulse counter in series in a circuit with the first switch adapted to register one unit each time the switch is closed whereby the number of units registered on the counter over a period of time is a measure of the integrated heat-absorbing capacity of the atmosphere over the same period of time; and a time-dependent second switch means in series with the impulse counter in a circuit excluding the first switch whereby time-dependent units are registered on the counter at a regular rate in addition to those registered in response to the action of the first switch.

2. Apparatus as claimed in claim 1 including a reverse-acting thermostat responsive to outdoor atmospheric temperature connected in series with the second switch whereby the registration of time-dependent units by the counter is discontinued below a predetermined atmospheric temperature.

3. Apparatus as claimed in claim 2 including a plurality of time-dependent switch means each connected in series in a separate circuit excluding the first switch with one of a plurality of reverse-acting thermostats, each thermostat being responsive to a different outdoor atmospheric temperature whereby the registration of time-dependent units on the counter in response to one of the time-dependent switch means is discontinued at an atmospheric temperature different from that at which the registration of units in response to another of the time-dependent switch means is discontinued.

4. Apparatus as claimed in claim 1 including a solenoid operated double-throw relay which comprises the first switch and a switch means whereby the circuit including the second switch means and the impulse counter is interrupted when the circuit including the first switch and the counter is formed.

5. Apparatus as claimed in claim 4 including a second impulse counter connected in a circuit in parallel with the solenoid of the relay and adapted to register one unit each time the solenoid is energized.

6. Apparatus as claimed in claim 1 including a normally closed time-delayed opening switch connected in series in the circuit with the time-dependent second switch means and the first impulse counter whereby the impulse counter is shunted out of the circuit at a predetermined interval after the circuit is formed.

7. Apparatus as claimed in claim 1 including a shunt switch operable simultaneously with the first switch means whereby a shunt circuit is formed around the thermostat controlling the heating means and continued operation of the synchronous motor is effected until the first switch means interrupts the circuit in which it is in series with the first impulse counter.

8. In apparatus for estimating the fuel oil consumption of a building utilizing oil both for space heating and for heating water, the combination including: a reference chamber having a heat-conducting wall adapted to have its exterior surface in heat-exchange relationship with the outdoor atmosphere; a source of E. M. F.; a constant voltage regulator; a thermostat inside the reference chamber connected in series with the primary circuit of the voltage regulator across the source of E. M. F. and set to close and energize the primary circuit when the temperature in the chamber falls to a predetermined reference temperature; an electrical heating unit inside the reference chamber connected in series with an adjustable resistance outside the chamber across the constant voltage secondary circuit of the voltage regulator; a first synchronous motor connected in a circuit across the constant voltage secondary circuit of the voltage regulator and operable, together with the heating unit, in response to the energizing of the primary circuit of the voltage regulator by the action of the thermostat; a solenoid-control switch operable mechanically at regular time intervals by the first synchronous motor during its periods of operation; a double-throw solenoid-operated relay switch, the solenoid and the solenoid-control switch being connected in series in a circuit across the source of E. M. F.; a first impulse counter connected in series with the solenoid-operated relay switch in a circuit across the source of E. M. F. formed when the solenoid is energized; a second synchronous motor connected in series with the solenoid-operated relay switch in a circuit across the source of E. M. F. formed when the solenoid is deenergized; and a counter-actuating switch operable mechanically at regular time intervals by the second synchronous motor during its periods of operation, the counter-actuating switch, the impulse counter and the solenoid-operated relay switch being connected in series in a circuit across the source of E. M. F. formed when the solenoid is deenergized.

9. Apparatus as claimed in claim 8 including a normally closed, time-delayed opening switch connected in series in the circuit with the counter-actuating switch, the solenoid-operated relay switch and the impulse counter whereby the impulse counter is shunted out of the circuit at a predetermined time interval after the circuit is energized sufficiently to cause registration of a unit by the counter.

10. Apparatus as claimed in claim 8 including a reverse-acting thermostat located in a suitable housing out of doors and connected in series in the circuit with the counter-actuating switch, the solenoid-operated relay switch and the impulse counter whereby the circuit is interrupted and the actuation of the counter by the counter-actuating swtich is prevented at atmospheric temperatures below a predetermined temperature setting of the reverse-acting thermostat.

11. Apparatus as claimed in claim 8 wherein the solenoid-operated relay switch includes a single-throw switch, the single-throw switch being connected in series with the first synchronous motor across the primary circuit of the voltage regulator forming a shunt circuit around the thermostat in the reference chamber whereby energizing of the secondary circuit of the voltage regulator is maintained upon interruption by the thermostat of the circuit through it until the solenoid is deenergized by the opening of the solenoid-control switch.

12. Apparatus as claimed in claim 8 including a second impulse counter connected in a circuit in series with the solenoid-control switch and in parallel with the solenoid across the source of E. M. F. whereby a unit is registered on the second impulse counter each time the solenoid is energized.

13. In apparatus for estimating the fuel oil consumption of a building utilizing oil for space heating and for heating water, the combination including: a reference chamber having a heat-conducting wall adapted to have its exterior surface in heat-exchange relationship with the outdoor atmosphere; a source of E. M. F.; a constant voltage regulator; a thermostat inside the reference chamber connected in series with the primary circuit of the voltage regulator across the source of E. M. F. and set to close and energize the primary circuit when the temperature in the chamber falls to a predetermined reference temperature; an electrical heating unit inside the reference chamber connected in series with an adjustable resistance outside the chamber across the constant voltage secondary circuit of the voltage regulator; a first synchronous motor connected in a circuit across the constant voltage secondary circuit of the voltage regulator and operable, together with the heating unit, in response

to the energizing of the primary circuit of the voltage regulator by the action of the thermostat; a solenoid-control switch operable mechanically at regular time intervals by the first synchronous motor during its periods of operation; a double-throw solenoid-operated relay switch, the solenoid and the solenoid-control switch being connected in series in a circuit across the source of E. M. F.; a first impulse counter connected in series with the solenoid-operated relay switch in a circuit across the source of E. M. F. formed when the solenoid is energized; a second synchronous motor connected in series with the solenoid-operated relay switch in a circuit across the source of E. M. F. formed when the solenoid is deenergized; a plurality of counter-actuating switches operable mechanically in succession at regular time intervals by the second synchronous motor during its periods of operation; a plurality of reverse-acting thermostats suitably located for sensing the outdoor atmospheric temperature and each adapted to interrupt a circuit through it at an atmospheric temperature below a predetermined temperature setting of the reverse-acting thermostat different from the temperature settings of the other reverse-acting thermostats, each series-connected set of one counter-actuating switch and one reverse-acting thermostat being connected in parallel with each other set and in series with the first impulse counter and the solenoid-operated relay switch in a circuit across the source of E. M. F. formed when the solenoid is deenergized; a normally closed, time-delayed opening switch connected in the circuit in series with the first impulse counter and each of the counter-actuating switches adapted to interrupt the circuit and shunt the impulse counter out of the circuit from the end of a predetermined time interval after the circuit has been formed by a counter-actuating switch until the circuit is interrupted by the switch; a single-throw relay switch operated by the solenoid and connected in series with the first synchronous motor across the primary circuit of the voltage regulator whereby the secondary circuit of the voltage regulator is maintained in an energized condition following each energizing of the solenoid until the solenoid-control switch causes the solenoid to become deenergized; and a second impulse counter connected in series with the solenoid-control switch and in parallel with the solenoid across the source of E. M. F. whereby a unit is registered on the second impulse counter each time a unit is registered on the first impulse counter in response to the energizing of the solenoid.

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