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1 ENERGY-SAVING HEATING VESSELS

The present invention relates to energy-saving heating vessels useful generally in laboratory, industrial, service and domestic fluid heating applications, in the form of laboratory ware, heating tanks, cooking utensils and fluid heating equipment generally.

It is estimated that there are over 30 million glass and glass-ceramic vessels of various types heated on hot plates and ranges in use in the United States today. These include vessels for heating coffee, tea, water, etc. and also laboratory ware, including a variety of beakers and flasks.

It is further estimated that in use about 15% to 20% of these vessels are heated on various types of contact heating surfaces, such as electric hot plates, ranges, etc., and that about 4.5 million of such hot plates are in use, having power ratings ranging from about 300 to 4000 watts for laboratory and industrial vessels and from about 1200 to 3600 watts for commercial and home use. On the basis of an average hot plate rating of 1500 watts and an average "on time" of about 3 hours, the total electrical energy consumed by such heaters amounts to over 20 million kilowatt-hours per day or 7,400,000,000 (7.4 billion) kilowatt-hours per year, a truly significant amount of energy.

1 The relatively large wattage required in such heating is due primarily to the following:

 (1) The nature of the material heated; usually this is mostly water, which requires more energy to
5 raise its temperature per degree than any other material involved, due to its high specific heat.

 (2) The material the vessel is made of, particularly the vessel bottom which contacts the hot plate surface. Since these vessels usually are made of glass, glass-
10 ceramics or the like, i.e. materials with low thermal conductivities, the heat transfer through the bottom of a vessel is considerably below that obtained through metals and graphite (as described herein), all other factors being the same. For example, the heat
15 conductance through graphite is about 125 times greater than through an equal thickness of glass.

 (3) The geometry of the vessel, particularly the surface of the vessel bottom which contacts the hot plate, which is an important factor in heat flow. With
20 glass vessels, their bottoms are frequently made concave, so that the vessels rest only on the periphery, i.e. a ring-shaped part, of the bottom surface. Therefore, the area of contact for heat transfer is greatly reduced. The bottom thickness is also a significant factor in the
25 heat transfer capability of a vessel; furthermore, if glass vessels are made with reasonably thin bottoms to improve heat transfer, they are very fragile and easily broken.

 Another important consideration in relation to
30 energy saving is the amount of energy required in the production of materials used in the manufacture of the vessels. For example, "U.S.I. News," Second Quarter/1979, (published by U.S. Industrial Chemical Co., 99 Park Avenue, New York, N.Y. 10016), referring to relative energy
35 consumed in the production of plastics, glass, steel and

1 aluminium, states: "To manufacture an equal weight
of each of these materials, it takes 1.4 kwh for
plastics, 3.6 kwh for glass, 6.3 kwh for steel and
33.6 kwh for aluminium". Thus, 5 times more energy
5 is required to produce the material for a glass
vessel than the material for the same size of plastics
vessel, since a plastics material (e.g., polypropylene
and others) has a specific gravity less than 1/2 that
of glass (0.90 instead of 2.23). The material for an
10 enamelled steel vessel, having a specific gravity of
about 7.8, requires 42 times the energy needed for
making a plastics vessel of the same size; an
aluminium vessel needs 48 times more energy than a
plastics vessel. In a like manner, an enamelled
15 steel vessel requires about 6 times the energy needed
for making a glass vessel and an aluminium vessel
about 9 times the energy needed for a glass vessel.
It is therefore evident that plastics materials are by
far the most conservative of energy, in relation to the
20 manufacture of vessels, with glass second and metals
being highly energy-intensive.

Still another consideration in energy conservation
is the thermal conductivity of the sidewalls of a vessel,
that is those surfaces not in contact with the hot plate
25 or other heat source. Here, thermal insulation is
desirable, in order to prevent loss of heat to the
surrounding air. From a qualitative point of view,
a plastics vessel containing very hot water can be
picked up at the top by means of the fingers, whereas
30 a glass vessel would be uncomfortable or painful to
the touch; a metal vessel would be too hot to handle
with a bare hand. This is due to the different thermal
conductivities of these materials, which in the same
units (btu) are 1.4 for polypropylene, 8 for glass,
35 360 for carbon steel and 1190 for aluminium alloy 6061.

1 Thus polypropylene and other plastics are good insulators,
glass is a fair insulator of heat and metals are good
conductors of heat, as is known. From the standpoint of
choice of materials of manufacture, it is clear that
5 making and using vessels partly or entirely of a plastics
material would conserve a significant amount of energy.
Plastics vessels can also be mass-produced economically and are un-
breakable, corrosion-resistant and non-contaminating to
many substances, depending on the polymer. Some, like
10 fluorinated ethylene/propylene (FEP), are much more
resistant to corrosion than glass. Others, like
polypropylene and polymethylpentene, are almost as
resistant as the fluorinated polymers. A large variety
of vessels and containers made of polyethylene, poly-
15 propylene and other polymers, i.e. plastics materials
generally, are widely available, having displaced glass
and metals in many applications.

However, as is well-known, plastics vessels cannot
be heated by contact with bottom surface heat sources,
20 such as hot plates, other heated platens and the like.
This is true even of plastics materials with relatively
high softening or melting temperatures, such as the
fluorinated polymers, e.g. "Teflon", (Regd. Trademark),
which have softening or melting temperatures in the
25 range from 400°-500°F (204°-260°C), well above the use
temperatures for most applications. The reasons for
this, as previously indicated, are the very low thermal
conductivities of these materials, which are heat in-
sulators, and also their relatively thick walls. Man-
30 ufacturers of plastics ware, particularly for laboratory
applications, such as beakers, flasks and the like, warn
their users about this. For example in the 1979 Plastic
Labware Catalog of the Nalgene Company, Division of Sybron
Corporation, a bold caution notice appears twice: "Do
35 not place plastic labware in a direct flame or on a hot

1 plate". The great need for a plastics-bodied vessel
which can be heated on a hot plate and for glass and/
or glass-ceramic vessels which maximize energy savings
both in manufacture and in use has led to the present
5 invention, which provides, i.a., a novel energy-saving
heating vessel which requires only $2/3$ to $1/4$ or less
of the energy now used by present-day glass, glass-
ceramic and similar types of heating vessels. This
energy saving can be attained by practising the present
10 invention as described hereinafter. The invention
provides energy-saving heating vessels and containers
which are suitable for all types of laboratory,
domestic, industrial and service applications. Thus,
the invention provides, for instance, vessels such as
15 beakers and flasks, coffee-making and coffee-heating
vessels and a variety of cookware, hot-water tanks,
pickling and plating tanks, stills, fermentation vats,
evaporating pans and the like.

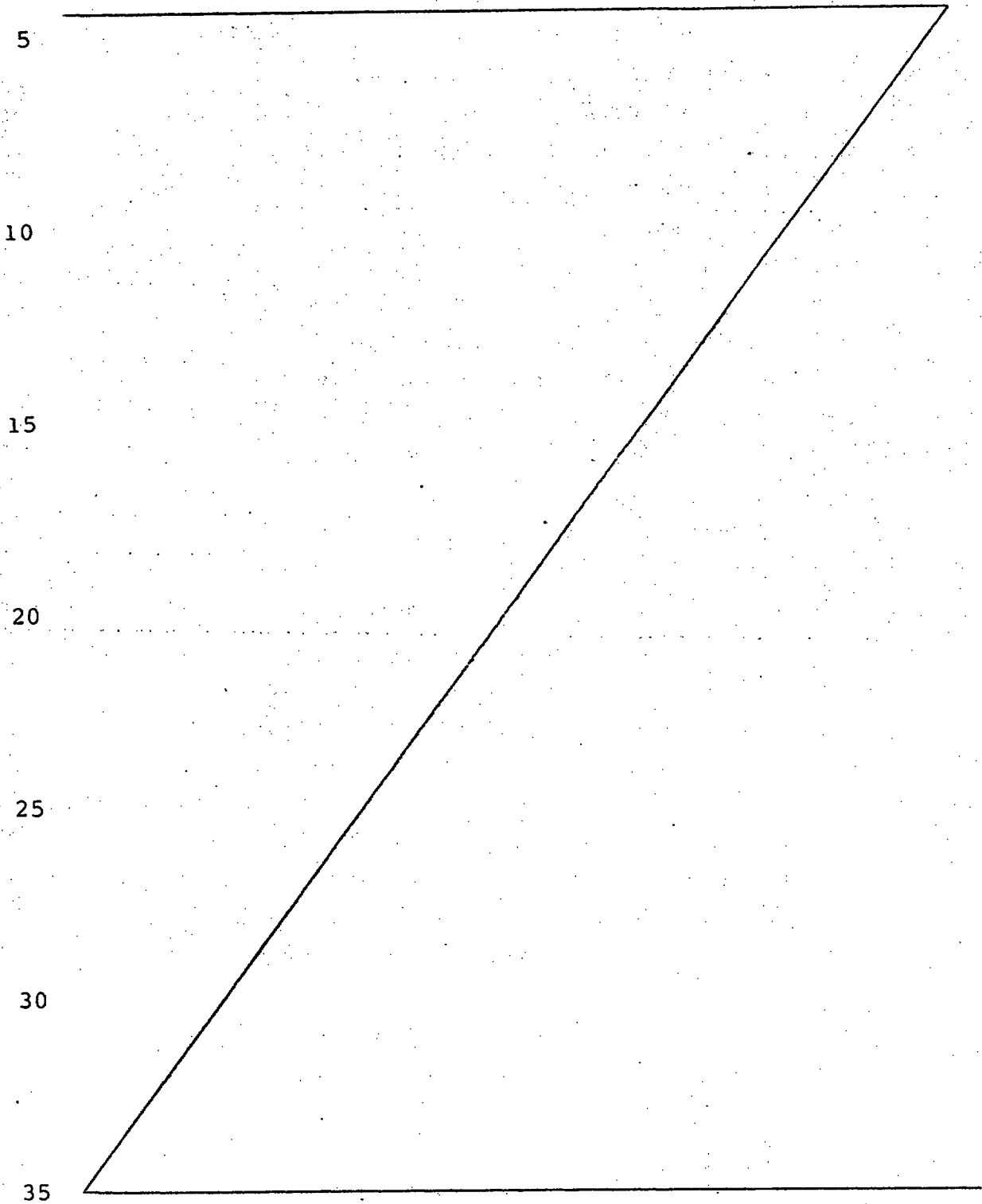
According to the invention, an energy-saving heat-
20 ing vessel is provided, having thermally-insulative side-
walls of a plastics material and a thermally-conductive
bottom, wherein the vessel bottom includes:

an inner layer of plastics material, providing
minimal resistance to heat transfer therethrough,
25 the thinness of the layer being limited only by
the requirement that it be liquid-impervious, and
an outer layer of thermally-conductive graphitic
material in thermal contact with and supporting
the inner layer, for thermal contact with a heat-
30 ing surface,
whereby the vessel in use serves to transmit heat
from such heating surface through the bottom to
the contents of the vessel and to retard the trans-
fer of heat from the contents through the side-
35 walls.

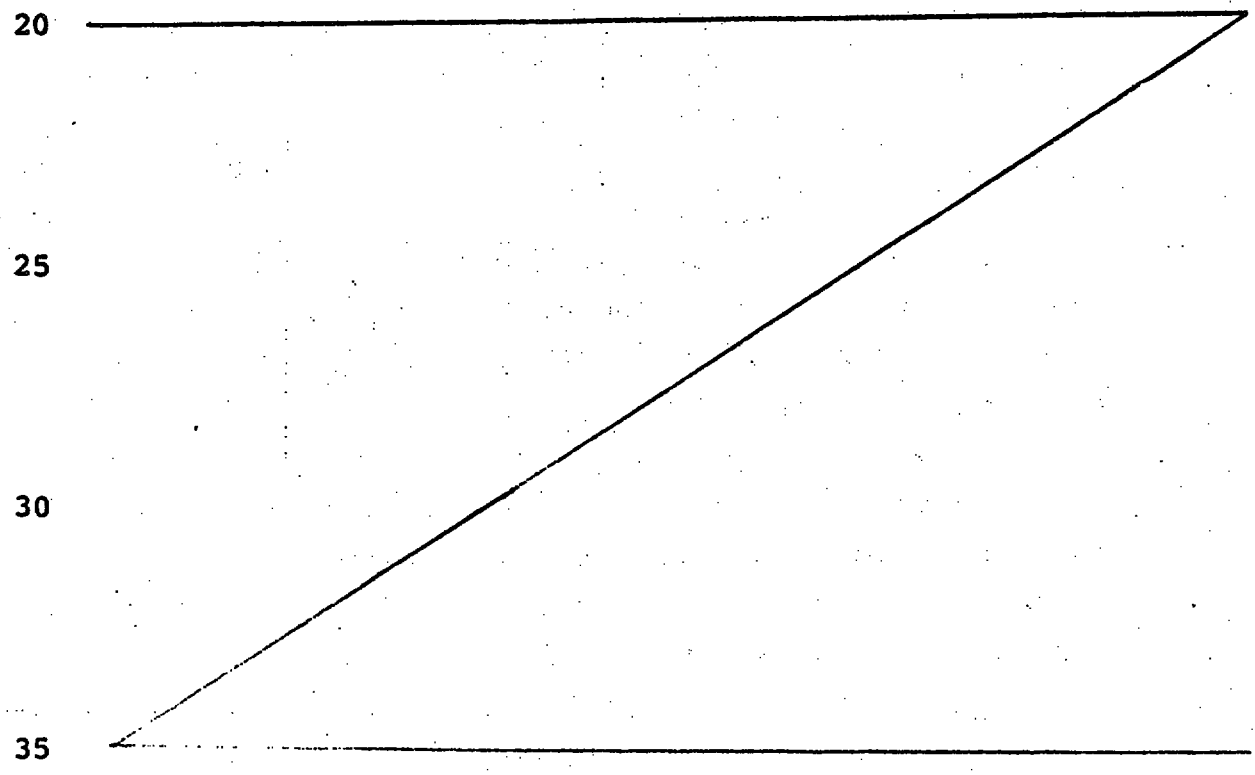
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1 Preferably, the inner layer is of the same material as the sidewalls and is continuous therewith. The inner layer preferably comprises a thermoplastic material.



1 The energy saved by the use of vessels of this
invention would be highly significant, as it could
amount to about 2.5 to 5.6 billion kwh or more per year,
i.e. about 2/3 to 1/4 (or less) of the energy now used
5 by glass, glass-ceramic and ceramic vessels heated on
hot plates and the like. A further energy saving
could result from the use of plastics materials for
heating vessels, both for the body of the vessel and
as a coating for the bottom elements of vessels of this
10 invention, since plastics are much less energy-intensive
than glass or metals and also are economical to manu-
facture. An embodiment of the vessel of the invention
is a plastics-bodied or walled heating vessel with a
graphitic bottom for good heat transfer, i.e. a bottom
15 containing or consisting of graphite, since such a
vessel not only saves energy, but also is virtually
unbreakable, compared to one made entirely of glass or
ceramics. Such a heating vessel is also highly corrosion-



- 1 resistant and anti-contaminating, comparing favourably
with glass. Such a vessel is also economical to
manufacture in a large variety of shapes and sizes
using existing equipment and facilities for the
5 manufacture of regular plastics ware.

Such a plastics-bodied or walled heating vessel
with a graphite or graphitic bottom not only can be more
rapidly heated to the desired temperature at a much
lower hot plate temperature than a similarly sized glass
10 vessel, but also heats up uniformly and the contents
boil smoothly without "bumping".

Another embodiment is a plastics-bodied or walled
heating vessel with a good thermally-conductive bottom
outer surface consisting of graphite or a graphite/carbon
15 material upon which is moulded or coated a thin plastics
film, i.e. on the service (inner) surface. A thin glass
layer may also be applied to the service side of the
graphite by coating or moulding.

Another embodiment of the invention is a plastics-
20 bodied or walled heating vessel with a graphitic or
plastics-coated graphitic composite bottom, where the
plastics material composing the body of the vessel or the
layer on the graphite is a corrosion-resistant non-toxic
anti-contaminating polymer. Among such polymers are the
25 polyolefins, particularly polypropylene and polymethyl-
pentene, and also the fluorocarbon polymers, such as
polytetrafluoroethylene (PTFE), ethylene/tetrafluoro-
ethylene copolymers (ETFE), fluorinated ethylene/
propylenes (FEP), polychlorotrifluoroethylenes (CTFE)
30 and polyvinylidene fluorides (PVDF), together with
polycarbonates, polysulphones and polyphenylene sulphides.
Where greater strength, abrasion-resistance and rigidity
may be required, a variety of anti-contaminating fibre-
reinforced polymers can be used, such as glass and graphite
35 fibre-reinforced and filled polyolefins and fluorocarbon

1 polymers.

5 An indirect advantage of the invention is the stimulus it gives to the design of new types of hot plates or heaters with much lower wattage ratings, for use in conjunction with the heating vessels of this invention. Such heater equipment could be advantageously used in conjunction with the vessels of the invention, since the latter would require much lower temperatures. and would result in even greater energy savings.

10 Another preferred embodiment of the invention lies in a plastics-bodied heating vessel having plastics walls and a highly thermally-conductive bottom consisting of a corrosion-resistant metallic material, including aluminium and its alloys, the stainless steels, nickel, 15 cobalt and copper-base alloys, titanium alloys, tantalum and carbon steels coated with a corrosion-resistant metal. Another feature of the invention comprises a plastics-bodied or walled heating vessel with a corrosion-resistant metallic bottom outer surface, as above, where 20 the bottom has a relatively thin layer of a plastics material on its internal or service side, consisting of a polyolefin, polyfluorocarbon, polycarbonate, polysulphone or other suitable corrosion-resistant anti-contaminating plastics or resin material, the plastics 25 layer being about 0.025 to 0.25 mm (1 to 10 mils) in thickness.

Another preferred embodiment of the invention is a plastics-bodied or walled heating vessel with a good thermally-conductive bottom comprising a corrosion-resistant anti-contaminating porcelain enamel or glass-ceramic material, coated on cast iron, steel, stainless 30 steel, nickel, cobalt and copper-base alloys, aluminium and aluminium alloys, where the coating is about 0.05 to 0.75 mm (2 to 30 mils) in thickness and where at least the 35 inner surface or preferably both the inner and outer

1 bottom surfaces are coated.

The invention further consists in a plastics-bodied or walled heating vessel with a porcelain enamel or glass-ceramic coated metallic bottom as described above, where the internal or service side of the bottom has a relatively thin coating layer of a plastics material on its service surface, consisting of a polyolefin, polyfluorocarbon, polycarbonate or other suitable corrosion-resistant anti-contaminating plastics or synthetic resin material and where the plastics layer is about 0.025 to 0.25 mm (1 to 10 mils) in thickness.

A further embodiment of the vessel of the invention comprises a plastics-bodied or walled heating vessel, having a graphitic or metallic bottom firmly secured to the sidewalls by an external metal band, clamp or other fastener located around the outer periphery of the vessel bottom, the metal band, clamp or other fastener being a corrosion-resistant metal or having a corrosion-resistant metallic or non-metallic coating.

Another embodiment of the vessel of the invention comprises a heating vessel having a glass, glass-ceramic or ceramic body or sidewalls with a heat-conducting bottom composition, suitable for laboratory, industrial, commercial and home applications, including those requiring heating on hot plates, smooth heating surface type ranges and the like, where the energy required in heating such a vessel is only 2/3 to 1/4 or less of that required in heating similar conventional glass, glass-ceramic or ceramic heating vessels. Another form of vessel of this invention comprises a part-glass, glass-ceramic or ceramic heating vessel with a thermally-conductive bottom comprising a graphitic material, such as graphite per se or a graphite/carbon material.

A further embodiment of the vessel of the invention comprises a non-metal heating vessel having a non-metal

1 wall and a graphitic bottom having a relatively thin
layer of a plastics material, glass or ceramic coated
on the service side.

Yet a further embodiment of the vessel of this
5 invention is a plastics-bodied or walled heating vessel
which can be heated on a hot plate or like heat source
by virtue of its having plastics walls and a heat-
conducting bottom, the bottom being a graphitic or
metallic material with its top or internal surface
10 bonded to a thin layer of plastics material which is the
bottom surface of the plastics-bodied vessel through
which most of the heat is conducted from the graphitic
or metallic material whose bottom or external surface
contacts the hot plate, the latter bottom surface being
15 flat or otherwise contoured to maximize surface contact
with the hot plate or other heating device.

Another preferred embodiment of the vessel of the
invention comprises an energy-saving glass or glass-
ceramic-bodied or walled heating vessel with a heat-
20 conducting bottom consisting of a graphitic material
with a relatively thin layer of glass, glass-ceramic
or plastics material on the top or internal surface of
the graphitic material, this surface being the area through
which most of the heat is conducted from the graphitic
25 material whose bottom or external surface contacts the hot
plate, the bottom surface being flat or otherwise con-
toured to maximize surface contact with the hot plate or
other heating device.

In order that the energy-saving vessels of the
30 invention and the methods of making them can be readily
understood and appreciated, reference is made to the
various illustrative embodiments shown in the accompanying
drawings and described below, by way of example; in the
accompanying drawings:

35 Fig. 1 shows a cross-sectional elevation view

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1 through a plastics-walled vessel having plastics side-walls 1 and a plastics material 4 coated onto a graphite or metal bottom 2 assembled with a heat-shrunk metal fastener 3 to form the vessel;

5 Fig. 2 shows a cross-sectional elevation view of a glass-walled vessel having glass side walls 21 and a plastics material 26 coated on to a graphite or metal bottom 22 assembled with gaskets 24,25 and a metal fastener 23 to form the vessel;

10 Fig. 3 shows a cross-sectional elevation view of a glass-bodied vessel having a moulded glass body 31 with a moulded glass inner layer 33 and a graphite or metal element 32 associated with the bottom of the vessel with at least one gasket 35 and a metal fastener 34;

15 Fig. 4 shows a cross-sectional elevation view of a plastics-bodied vessel having a moulded plastics body 41 and a moulded plastics inner layer 43, a graphite or metal element 42 being associated with the bottom of the vessel with a heat-shrunk metal fastener 44;

20 Fig. 5 shows a cross-sectional elevation view of a moulded glass-bodied coffee flask 51 with a moulded glass inner layer 53, having a graphite element 52 retained at the bottom of the flask by moulded glass projections 54 located in corresponding recesses in the
25 graphite element;

Fig. 6 shows a cross-sectional elevation view of a moulded plastics-bodied coffee flask 61 with a moulded plastics inner layer 63 and a graphite or metal element 62 associated with the bottom of the flask with a
30 fastener 64;

Figs. 7-12 are charts of time-temperature data obtained while heating water in energy saving vessels of the invention compared to heating water in conventional glass vessels.

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DETAILS OF THE INVENTION

The energy saving heating vessel of this invention comprises a non-metal bodied vessel with plastic, glass, glass-ceramic, or ceramic sidewalls and a novel heat conducting bottom of a graphitic or metallic material, or coated graphitic or metallic material. The vessel may readily be manufactured by use of various known procedures.

In a preferred form, the body of the vessel is molded with a graphite, graphitic material, metal or metallic bottom element insert including retaining means for the insert. In another form, the energy saving vessel is fabricated from a tubular element with an open bottom end, to which is fitted a composite graphitic or metallic bottom secured by suitable means, preferably by a metal band, clamp, or other fastener.

In Fig. 1, which is a cross section of a plastic walled cylindrical heating vessel with a composite bottom assembled in accordance with this invention, 1 is the plastic vessel side wall, 2 indicates the graphite element of the composite bottom with a thin coating layer of plastic 4 over the internal surface of the graphite element, 3 indicates a metal band or ring which is heat-shrunk to the side walls and firmly secures the bottom, to the plastic vessel walls. In this illustration, the composite bottom 2 may also be a metal, the thin layer 4 may be a plastic, or a porcelain-enamel on an internal metal bottom surface, or a porcelain-enamel coating may be present on both sides of a metal bottom.

A similar assembled vessel is shown in Fig. 2, which in this case is a cross section of a glass walled cylindrical heating vessel with a composite bottom assembled in accordance with this invention, where 21 is the glass vessel side, 22 indicates a graphite element of the composite bottom, 26 indicates a plastic film over the internal surface (service side) of the graphite element, 24 and 25, are internal and external gaskets, respectively, such as flexible graphite ('Grafoil'), 23 indicates a metal band which is clamped to the graphited side-walls, and firmly secures the graphite bottom to the vessel walls and layer 26.

The energy saving vessels of this invention may also be manufactured by the following preferred procedure. The desired plastic, glass, glass-ceramic, or ceramic vessel is molded as a one piece configuration or body with the graphitic, or metallic bottom used as an insert to the bottom of the vessel during the molding process. As in the previously described vessels, a mechanical fastener means, such as a metal clamp, band or other fastener is used to firmly secure the bottom, although in some types of glass, or glass-ceramic vessels it may not be required. The vessel of Fig. 4 is a cross section of a molded plastic bodied heating vessel in accordance with this invention where 41 indicates the plastic sidewall continuous with the relatively thin molded plastic bottom layer 43 (or bottom area of the plastic vessel) over the internal surface of the inserted graphite or metal element 42, which is molded to the plastic and enclosed by the plastic except for the external bottom surface, 44 is a metal band which preferably is heat-shrunk to the sidewalls and firmly secures the element 42 to the plastic sidewalls at the base.

Fig. 6 is a cross section of a molded plastic bodied round vessel, (e.g., a coffee type flask), in accordance with this invention, where 61 indicates the plastic sidewall continuous with the relatively thin plastic vessel bottom 63, over the internal surface of the inserted graphitic or metallic element 62, molded to the plastic body, 64 is a metal band which preferably is heat-shrunk to the sidewall and firmly secures the bottom to the plastic sidewalls at the base of the vessel.

In Fig. 3, which is a cross section of a glass molded bodied heating vessel, in accordance with this invention, 31 represents the glass sidewalls continuous with the relatively thin molded glass layer or bottom glass area 33, over the internal surface of the inserted graphite element 32, molded to the glass at the base of the vessel, 35 is an external gasket, such as flexible graphite, 34 indicates a metal band which preferably is clamped to the sidewall and firmly secures the graphite element to the sidewall at the glass base.

In Fig. 5, which is a cross section of a molded glass spherical vessel (i.e. a coffee type flask) in accordance with this invention, 51 represents the glass sidewall continuous with the relatively thin molded glass vessel bottom 53, over the internal surface of the convex shaped inserted graphite disc element 52, molded to the glass; small openings, or recesses 54, made in the graphite (size magnified in drawing) filled with glass during the molding process further insure a bonding interlock or fastening of the glass to the graphite. A separate metal band or ring is not needed with this design.

In the following and previous descriptions, the terms "plastic/graphite", "plastic/coated graphite", and the like, will be used to define

the wall/bottom relationships of the novel heating vessel materials. Reference will also generally be made to plastic bodied or walled vessels, plastic bodied vessels, glass walled vessels and glass bodied vessels in most cases, rather than referring specifically in each instance to all the various physical forms or geometries, compositions, and the like that the vessels or containers of this invention can have, such as beakers, flasks, evaporating or pickling tanks, stills heat exchangers, various hot water heating tanks, coffee making flasks, cookware, and the like. It is intended that this description also apply to such other physical forms of heating vessels which can be heated by direct contacts with a heat conducting heating means. Also, reference will generally be made to the composite graphitic bottom in most cases, rather than referring specifically in each instance to all the various graphite, carbon, graphite/carbon types, the infiltrating resins, coatings, molding films, and the like. It is intended that this description also apply to such other types and modifications.

Also reference will generally be made to the metallic or metal bottom in most cases, rather than referring specifically in each instance to all the various metals, alloys, plated metals, porcelain enamel coated metals, or all the plastic and resins used to coat such metal bottoms. It is intended that this description also apply to such other types and modifications and that the terms "plastic/metal" and "plastic/coated metal" and the like define such vessels.

Also reference will generally be made to suitable fastener means, such as the metal band or ring, or clamp, rather than referring specifically in each instance to all the various metal and alloy compositions, the shapes, configurations, of the bands or the rings, straps, clamps, or other mechanical

fasteners which can be used. It is intended that this description also apply to such other types of fastening means. Mechanical fastening means usually are required to secure the bottom and vessel walls together in liquid-tight combination especially when the coefficients of expansion of the bottom and vessel walls are widely different. In some cases where the coefficients of expansion permit, solvent- and heat-proof sealants, or the plastic or glass vessel wall material, may be found suitable as fastening means.

Also reference will be made to glass bodied or walled vessels rather than referring specifically in each instance to all the various physical forms, compositions, types, the vessels of this invention can have, such as beakers, flasks, tanks, stills, heat exchangers, hot water heaters, coffee flasks, cookware and the like, also glass composition, glass-ceramics, ceramics and the like. It is intended that this description also apply to such other types and modifications.

Energy saving plastic vessels hereof may be manufactured from a large variety of commercial polymers and resins depending on the type of application. Thermosetting or thermoplastic polymers and resins can be used. However, the polyolefin and fluorocarbon polymers are most suitable for the vast majority of applications and are preferred. Of these, the fluorocarbon polymers are the most inert with the highest melting or softening temperatures. Among these may be mentioned FEP (fluorinated ethylene propylenes), PTFE (polytetrafluoroethylene), ETFE (ethylene/tetrafluoro ethylene copolymers), CTFE (polychlorotrifluoroethylenes), and PVDF (polyvinylidene fluorides). Of these, polymers, FEP is preferred for industrial uses, since it is even more inert than borosilicate or other glasses

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and ceramics. FEP is readily fabricated in a variety of vessel shapes and sizes, has a high use temperature of 205°C (401°F), and is transparent. It is a near ideal material for use in the presence of strong acids, alkalies, oxidizing chemicals, and aggressive solvents.

However, for general use with a majority of chemicals and virtually all food stuffs, the polyolefins are very satisfactory, being non-toxic, anti-contaminating materials that can be used at temperatures up to 175°C (347°F), and are much lower in cost than fluorocarbon polymers. Among the polyolefins, polypropylene, and polymethylpentene are preferred, although linear polyethylene and the newer ultra high molecular weight polyethylenes also may be used. Polypropylene is an excellent non-contaminating polymer with a use temperature up to 135°C (275°F), is tough, and is translucent. Polymethylpentene is also a good noncontaminating plastic with a use temperature up to 175°C (347°F), with excellent transparency. Costwise, polypropylene is about 1/15th the cost of FEP, and polymethylpentene about 1/8th the price of FEP.

Another preferred polymer, polycarbonate, is characterized by its outstanding strength, rigidity, and toughness, and excellent transparency. It is non-toxic material suitable for many chemicals and foodstuffs. It has a use temperature up to 135°C (275°F). Its cost is about 1.5 times that of polypropylene. The polysulfones are another group of preferred polymers for our novel vessels. Like the polycarbonates, they are transparent, of high strength, and anticontaminating for foodstuffs, biologicals and many chemicals. They may be used at temperatures up to about 200°C (405°F).

Polyphenylene sulfide polymers are high performance materials with excellent corrosion resistance and are anticontaminating, being particularly well suited for chemical processing applications.

- 5 The above plastics and many others are presently used in an ever-increasing, wide variety of vessels and containers, some of which are patented. For example, a plastic heating vessel having a flexible plastic bottom for use in

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cooking particularly on a specifically designed and heat controlled heating surface is described by Bohdan Hurko in U.S. 3,971,361. However, the inventors hereof are not aware of plastic walled or bodied vessels being used directly on conventional hot plates, ranges, or other similar types of heating devices in the manner of their energy saving heating vessel. As previously indicated, this is due to the known relatively poor thermal conductivity (T.C.) and relatively low melting or softening or decomposition temperatures of most polymers. For example, polypropylene (PP) has a thermal conductivity of about 1.3 and a softening temperature of under about 300°F, compared to a T.C. of 8 for a borosilicate glass which has a softening temperature of about 1500°F, and compared to graphite which has a thermal conductivity of 975. In the description herein, all "thermal conductivity" data is in btu/hr/sq. ft./°F./in.

20 To these thermal disadvantages of plastics must be added the need for thicker vessel walls and bottoms, as compared to metal vessels, because of the much lower elastic moduli and rigidities of plastics, particularly at elevated temperatures. Thus a polypropylene beaker of 250 ml capacity has a wall and a bottom thickness of about 0.060 in. Glass vessels, too, are made to about the same thickness as similar plastic vessels, primarily because of their brittleness and fragility.

30 Furthermore, the bottom of such a conventional plastic vessel is not flat, but is more or less concave, like that of a similar glass vessel. Consequently, both vessels have a relatively small heating contact areas when placed on flat surface, such as a hot plate. These low contact characteristics of the vessels result in relatively low heat transfer by conduction, or low heat flow per unit time. As

is known, the "heat flow rate" of the vessel bottom material is directly proportional to its thermal conductivity and surface area of contact, and is inversely proportional to its thickness.

- 5 "Heat flow rate" is also directly proportional to the temperature difference between the bottom and top surfaces of the heated bottom in a perpendicular direction; however, this is a variable heat factor in contradistinction to the basic physical
- 10 characteristics of the material itself, that is, "thermal conductivity", and geometry (i.e. thickness, flatness, contact areas). Therefore, by "heat flow capability" we mean the "thermal conductance" of the material times its surface area of contact, with
- 15 "conductance" being the "thermal conductivity" of the material divided by its thickness. It can therefore, be seen that a vessel bottom with a low thermal conductivity, a relatively thick cross section, and a small area of contact, is unfavorable to good
- 20 heat transfer, all other factors being equal, as is illustrated in Table I hereof. We have found that a unique and novel energy saving, plastic bodied or walled heating vessel that can be used on a conventional hot plate, can be produced, by incorporating in such
- 25 a vessel, a relatively thin impervious non-metal, e.g. plastic bottom area, and mechanically supporting this thin area by physically contacting or molding it to a rigid graphitic, or metallic material having high thermal conductivity, and with a heater contacting
- 30 bottom outer surface that is relatively flat or otherwise contoured to make maximum thermal contact with a hot plate surface, or the like. The thin plastic bottom area of the novel vessel may be molded continuous with the plastic walls of the vessel as in
- 35 Figs. 4, 6, or such a thin plastic bottom may be incorporated in the novel vessel by molding, or coating a relatively thin plastic layer to the top surface

of a graphitic, or metallic, element, or bottom piece, (42,62) and inserting it into the base of the open ended vessel, and firmly sealing and securing it to the bottom end of the plastic vessel by means of a metal band, clamp or other fastener means, as shown in Fig. 1. The internal surface of the novel vessel is therefore all plastic. This plastic layer, bonded to, and supported by, the graphitic, or metallic element, or bottom piece, is part of a composite bottom which is in effect the thin plastic bottom area of the plastic walled heating vessel. Heating a relatively thin plastic layer on the graphitic or metallic element is equivalent to placing the thin plastic layer on a hot plate, since the top surface temperature of such a graphitic, or metallic material is essentially about the same as the temperature of the hot plate surface. For example, discs of graphite and aluminum about 0.250 in. thick placed on a hot plate at a surface temperature of 550°F, registered temperatures of about 535°F on their top surfaces, after about 30 seconds, or were about the same temperature as the hot plate. The plastic layer thus is directly exposed to such temperature and would melt except for the presence of a liquid on its service surface to remove the heat.

Another important advantage of the thin plastic bottom layer is its good contact with the inner surface of the graphitic, or metallic element, since it is molded, coated, or otherwise bonded contiguous to the surface of these good heat conducting materials. This means that virtually its entire surface makes excellent contact with the heat source via the graphite, or metal, bottom piece. It is also relatively easy to machine a flat or contoured bottom surface on a graphite or a metal

element, allowing good contact to be made with a hot plate surface. However, the need for this flatness is not as stringent as it would be for a material such as a plastic or glass with poor thermal conductivity, and therefore poor heat distribution, further accentuated by the uneven or concave bottoms characteristic of such vessels produced by molding. Thus it can be seen why uniform heating is obtained with the energy saving vessels hereof, in contrast to the relatively non-uniform, hot-spot, heating of conventional glass vessels, and why it is not feasible to use a conventional plastic vessel, such as a plastic beaker, on a hot plate.

The very large difference in heat flow rate capability of a conventional plastic vessel bottom and our composite vessel bottom is shown by Table I hereof. Table I shows a comparison of the thermal characteristics of the energy saving vessels hereof vs. glass and plastic vessels.

Referring to Table I, the table shows a comparison of thermal characteristics of bottoms of energy saving vessels hereof vs. bottoms of conventional glass and plastic vessels. The table lists the thickness l of the bottom in inches; thermal conductivity, T.C., $\text{btu/hr./sq. ft./}^{\circ}\text{F./in.}$; thermal conductance, U , where $U = K/l$; heat surface contact area, A , in sq. ft. ; heat flow rate capability, UA , in btu/hr ; and heat flow rate capacity ratios of a vessel bottom of the invention "Bot." vs. a conventional glass beaker bottom "A", or Bot/A ; (b) a vessel bottom of the invention "Bot" vs. a conventional polypropylene beaker bottom

"C" or Bot/C; and (c) a vessel bottom of the invention
Bot. vs. a comparable teflon (FEP) bottom material
"L", or Bot/L.

TABLE I
THERMAL CHARACTERISTICS OF BOTTOMS OF ENERGY
SAVING VESSELS VS. BOTTOMS OF GLASS
AND PLASTIC VESSELS

5			Total	Thermal	Thermal
			Thickness	Conductivity	Conductance
	<u>Bottom</u>	<u>Material</u>	<u>l (in.)</u>	<u>K</u>	<u>U</u>
	A	Glass	.0625	8	128
10	B	Impervious Graphite	.250	975	3900
	C	Poly. Prop. Plastic	.060	1.3	22
	D	Poly. Prop./ Graphite	.003 .250	1.3 975	390 (comb.)
15	E	Teflon FEP/ Graphite	.010 .250	1.44 975	139 (comb.)
	F	FEP/ Graphite	.003 .250	1.44 975	427 (comb.)
20	G	Glass/ Graphite	.025 .1875	8 975	301 (comb.)
	H	FEP/ Aluminum	.003 .250	1.44 1070	432 (comb.)
	I	Porc. enamel/ C. Steel	.016 .125	8 360	426 (comb.)
25	J	FEP Plastic Porc. enamel/ C. Steel	.002 .016 .125	1.44 8 360	268 (comb.)
	K	S. Steel. (304)	.200	105	525
30	L	Teflon FEP	.010	1.44	144
	M	Polymethyl- pentene/ graphite	.003 .250	1.40 975	417 (comb.)

Table I Continued

5	Heating Surface Contact Area, A Sq. Ft.	Heat Flow Rate Capability Btu/Hr	Bottom Heat Flow Rate Capability Ratios		
			Bot/A	Bot/C	Bot/L
	.010	1.28		5.8	.10
	.088	343	268	1559	27
	.010	.22	.017	--	.02
10	.088	34	26.6	155	2.7
	.088	12.2	9.5	55	.96
	.088	37.6	29.3	171	3.0
	.088	26.5	21	120	2.1
	.088	38	29.7	173	3.0
15	.088	37.5	29.3	170	3.0
	.088	23.6	18.4	107	1.9
	.088	46.2	36.1	210	3.6
	.088	12.7	9.9	58	--
	.088	37	29	168	2.9

Footnotes to Table I:

- The amount of heat transferred by conduction (Fourier's Law) $Q = KA \Delta T / l$ where Q = heat transferred per unit time, or heat flow rate, (B.T.U./Hr), A = area perpendicular to heat flow (Sq. Ft.), l = thickness (in.)
- 5 K = thermal conductivity of material (B.T.U./Hr/Sq. Ft./°F/in.) ΔT = temperature diff. between sides of bottom material through which heat flows. Law of conductivity may also be stated, $Q = UA \Delta T$ where U
- 10 U is conductance (k/l) combined conductances in layers, as plastic over graphite $\frac{1}{U} = \frac{1}{U_1} + \frac{1}{U_2} + \frac{1}{U_3}$ --- U_1 is plastic, U_2 graphite, etc.
- Contact area refers to 4 in. dia. bottoms in sq. ft. All bottoms the same diameter. Heat flow
- 15 rate 'capability' (UA) is used here to indicate the material factors such as thermal conductivity (k) and geometry (surface area of contact (A) and thickness (L) of a bottom material, that determine heat flow rate capability and not including process
- 20 variables such as temperature (ΔT), assuming all such conditions are equivalent in comparing bottom materials.
- Heat flow rate ratios: Bot/A , where Bot is vessel bottom material, A is glass bottom .0625 in. thick. Bot/C , where Bot is vessel bottom material,
- 25 C is polypropylene bottom .060 in. thick. Bot/L , where Bot is vessel bottom material, L is teflon FEP bottom material .010 in. thick.

Referring to the discussion above and to Table I relating to a conventional plastic beaker, the conventional plastic vessel is a 4 in. diameter beaker with a polypropylene bottom C about 0.060 in. thick. The invention beaker is a similar polypropylene 4 in. dia. beaker except the composite bottom D consists of a 0.003 in. thick polypropylene layer bonded to a 0.250 in. thick graphite supporting bottom piece. The thermal conductivity, I , is the same, 1.30, btu/hr./sq. ft./ $^{\circ}$ F./in., for both plastic bottoms, C and D, but the thermal conductance, U , is only 22 for the 0.06 in. thick plastic bottom, C vs. 390 for the composite graphite/plastic bottom D, or about 18 times greater. Since the bottom contact area of the conventional beaker is only about 1/10th that of the plastic/graphite bottom, the heat flow rate capability, UA , of the composite plastic graphite bottom, D, is $34/.22=155$ times greater. This illustrates the unique thermal characteristics of the energy saving vessel.

It can also be seen in Table I that a FEP (0.003 in. thick) plastic, and an aluminum 0.250 in. thick bottom H, of total thickness of 0.253 in. has about the same high heat flow rate capability ratio, $38/.22=173$, as bottom D. Again referring to Table I, a carbon steel bottom piece coated with 0.008 in. of a porcelain-enamel on each surface, plus a 0.002 FEP plastic film bonded to its top surface, (J), has a combined thermal conductance, U , of 268, or 12.2 times greater than the plastic bottom 0.060 in. thick, and a heat flow rate capability 107 times higher.

Like the plastic vessels of this invention, we have also found that a unique and novel energy

saving glass, glass-ceramic or ceramic vessel that can be used on a hot plate, a smooth top range, and the like, can be produced by incorporating in such a vessel, a relatively thin glass bottom area, and mechanically supporting and protecting, this fragile, impact sensitive bottom area, by bonding it to a rigid graphitic material having good thermal conductivity, K, and with a bottom that is relatively flat or otherwise contoured to make maximum contact with the hot plate surface or the like. The thin glass bottom area, may be made continuous with the rest of the glass vessel, as shown in Figs. 3,5, or such a thin glass bottom may be incorporated as the bottom in the glass vessel, by molding a relatively thin glass layer to the top surface of a graphite bottom piece, of about the same coefficient of expansion as the glass, and securing it to the open ended base of the vessel with internal and external flexible graphite gaskets, or the like, and a metal band, clamp, or fastener, as shown in Fig. 2. A thin plastic layer or coating can also be molded or coated to the graphite bottom piece, instead of the glass layer, and secured to the glass vessel as described above. This is also shown in Fig. 2, where 26 may be a plastic or a glass, layer or surface. The advantages of a substantially all glass vessel with such a composite glass/graphite, or plastic/graphite bottom are many, including uniform heating without bumping, more rapid heating rate, lower hot plate temperatures, significant energy savings, greater safety, because of the more rugged composite bottom, and others. From Table I, it can be seen that a composite glass/graphite bottom, G, consisting of a 0.025 in. thick glass layer and 0.1875 in. thick graphite, has a combined thermal conductance, U, of 301, compared to 128, for a conventional glass bottom A, 0.0625 in. thick. The glass layer on the graphite could be made considerably

thinner than 0.025 in., but even so it has 2.4 times the thermal conductance, U , and 21 times the heat flow rate capability, UA , of the conventional glass bottom. As previously mentioned, the uneven or concave bottom surfaces of conventional glass vessels drastically reduce the area of heating surface contact of the bottom. In this case it is only about 1/10th that of the composite bottom, or .010 sq. ft. vs. .088 sq. ft.

10 We have described two types of novel vessels of this invention, a plastic, and a glass type; however, such vessels can be modified with a wide variety of materials, and with a broad selection of geometries, that can be used in numerous applications.

15 The bodies of the plastic vessels can be made of the many polymers already mentioned, and used commercially for vessels and containers. The bodies of glass vessels can be made of the many types of glasses used commercially for vessels, particularly the borosilicate types, or the commonly used glass-ceramics, particularly those types used for cookware, coffee

20 vessels and the like. Certain types of impervious ceramic materials may also be used. Since the above materials are well known to those familiar with plastic, and glass and ceramic technology, we will

25 not further discuss these, only insofar as they pertain to the composite vessel bottoms of our invention.

The composite vessel bottoms of this invention can be made of a variety of coated or composite, graphitic, or metallic materials, or they may be uncoated metallic or graphitic materials. The innermost, thin plastic bottom of the plastic vessel can be formed continuous with the plastic body of the vessel, being supported by and bonded to the graphitic or metallic bottom piece by molding, as previously

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described, and as shown in Figs. 4 and 6. In a like manner, as shown in Figs. 3 and 5, the thin glass bottom of the glass vessel can be made continuous with the body of the vessel, being supported by and bonded by molding to a graphitic bottom insert piece.

A metallic bottom piece is not recommended in glass vessels because of the large difference in thermal expansion coefficients, particularly with borosilicate glass compositions.

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In plastic vessels of the type shown in Fig. 1, where the composite bottom element 2,4 is inserted, and secured to the open ended base of the vessel, the thin plastic layer 4 can be a plastic film molded to the graphite 2, or a coating, sprayed, dipped, painted, or otherwise applied. The plastic preferably is selected from polyolefin, polyfluorocarbon, polycarbonate, or other suitable corrosion-resistant, anti-contaminating polymer, or resin, including fiber reinforced or filled plastics. The bottom plastic may be the same material as that used for the vessel body, or another type, such as a glass filled polymer, for greater abrasion resistance. The plastic layer 4 preferably is about 1 to 10 mils (0.001 to 0.010 in.) thick. Although a somewhat thicker layer may be used for certain applications, it is generally not recommended because of its much lowered conductance. A resin infiltrated graphite, element 2 coated with the same resin 4 may also be used. A graphite, element 2 infiltrated with a FEP fluorocarbon resin and coated on the top surface with about 3 mils of the same resin 4 is described in Example 1.

The selection of a graphitic material as a heating surface contacting, heat conducting vessel bottom element is based not only on its good thermal conductivity, but on its excellent corrosion resistance, anti-contaminating, non-toxic nature, also its good fabricability, machinability, lightweight, excellent heat shock resistance, relatively low cost and availability. It is also virtually warp proof, when placed on heated surfaces. Graphite has been used for many years in the chemical and food processing industries for

processing such materials, as hot concentrated sulfuric acid, pharmaceuticals and fruit juices. The impervious type of graphite, e.g. "Karbate" is generally used in such applications, because heat exchanger processing, generally used in such applications, is carried out under pressure. Since graphite, as manufactured, is ordinarily too porous to be used under pressure, except for specialized types, such as pyrolytic graphite, it is impregnated usually with a resin, generally a phenolic, epoxy, furan, or a fluorocarbon resin. The most common type of impervious graphite, "Karbate" (Union Carbide trade mark) is 85 to 90% by weight graphite with the balance generally being a phenolic resin. For most of the applications involving the vessels of this invention, little or no pressure above atmospheric is used; therefore, graphites, or graphite/carbon materials with some porosity may be used, particularly if a plastic layer is bonded to the inner service surface. Carbon is sometimes added to graphite to improve its hardness or abrasion resistance; however, it significantly lowers the good thermal conductivity of graphite. Carbon is also more abrasive and difficult to machine. There are various grades of graphite with varying strength, hardness, abrasion resistance, bulk density, porosity, permeability, thermal conductivity, thermal expansion, etc. Where a thin layer of plastic is to be bonded to the surface, a grade of graphite with a relatively fine to medium grain structure and a bulk density of about 1.7 g/cc or over is satisfactory. Where graphite or graphite/carbon is used as a bottom piece without a coating, it is desirable to use an impervious

variety. As previously stated, an impervious graphite with a thin layer of plastic is very satisfactory. as shown in Table I, Bottom B.

5 The thickness of the graphite bottom will depend largely on the vessel geometry, particularly the diameter. For example, graphite, about 1/8 to 3/8 in. thick is satisfactory for vessels up to about 4 to 5 in. diameter, as the bottom contact area, whereas vessels about 6 to 12 inch diameter
10 would require a thickness of about 3/8 to 3/4 in. Such vessels may also require metal supports attached to the bottom metal band.

15 Metal elements of composite metal bottoms for plastic bodied or walled heating vessels may be considerably thinner than graphite elements because of their higher elastic moduli or greater rigidity, and strength, with a thickness range of about 1/16 to 1/4 inch for vessel bottoms up to about 12 in. in diameter. The use of metals as vessel bottom elements
20 is based on their good thermal conductivities. Some, like copper and aluminum, have even higher thermal conductivities, than does graphite. Some, like the 300 series stainless steels, have lower K values. Metals are also strong, tough, easy to fabricate and
25 readily available. However, the stainless steels, nickel and cobalt base alloys are expensive and contain elements that are becoming increasingly scarce. These alloys are also the ones primarily used for corrosion resistance in the chemical processing and related industries. Aluminum,
30 copper, nickel, iron, titanium, and their alloys, and tantalum, can be used as vessel bottom elements. This represents a very large variety of metals for bottoms, most of which are best used coated. Only the stainless, corrosion-resistant,
35 anti-contaminating metals can be used uncoated, and these in a relatively limited range of

applications. For example, we are all familiar with metallic taste imparted to a variety of foods and beverages. Like the graphitic materials, metals may be coated with a plastic, or have a thin plastic layer molded to its top surface, Fig. 1. Metals may also be used as inserts in the molding of plastic bodied vessels as previously mentioned, Figs. 4,6. The plastics and resins that may be used are the same as those previously described for use with graphitic composite bottoms. Comparing plastic coated graphitic and metallic materials, it is evident that in the event of damage to the plastic layer, a graphitic bottom would not be attacked, or be contaminating to the media, whereas a metal bottom would be much more vulnerable.

Metals coated with porcelain enamels, glass-ceramics, and glassed-metals, constitute a group of composite materials that are very useful as vessel bottoms for plastic bodied or walled vessels. A variety of metallic materials may be coated with these glass type coatings including the carbon steels, stainless steels and other stainless alloys, also the aluminums, however, the low carbon steels and 'Ti-Enamel' steels, are commonly used. The general practice is to apply a ground or bonding coat to the metal followed by one or more cover coats. These composite materials have good thermal conductivities provided the coatings are not too thick. The thermal characteristics of a porcelain-enamelled/carbon steel bottom are shown in Table I, bottom I. In this example, a 0.125 in. thick carbon steel disc is coated with 0.016 in. of porcelain enamel; (0.008 in. on each side). It can be seen that the combined thermal conductance and heat flow rate capability are about the same as that of plastic coated graphite bottom D, and of plastic coated aluminum bottom H.

Each of these has a heat flow rate capability about 28 times greater than does glass bottom A (0.0625 in. thick).

A wide variety of coating glasses or enamels and glass-ceramics are available depending on the application. These are all well known, as are the methods of processing used by those familiar with the technology. For general, broad applications, where excellent corrosion resistance, anti-contamination, and relatively good thermal shock is required, a coating with properties and characteristics similar to those of a borosilicate glass is generally used. Porcelain-enameled steel or other porcelain-enameled and glass-ceramic coated metals may be coated with a thin layer of plastic. For example, a 0.002 in. film of a fluorocarbon polymer can be used for protection of the porcelain coating from a hot caustic solution. The FEP coated porcelain-enameled steel bottom J of Table I with the 0.002 in. plastic would still have relatively good thermal conductance, with a heat flow capability 18 times that of a glass bottom A.

The porcelain enamel bottoms, I and J are secured to plastic walled vessels by metal bands or clamps in the same way as the graphite or metal bottoms. (Figs. 1,4,6, bottoms 2,42,62). A metal band, clamp, or similar fastening device is required to retain the graphitic or metallic bottom piece at the base of the plastic vessels, Figs. 1, 4,6, or to the glass vessels Figs. 2,3, although the bottom, as an insert, can be molded to the plastic vessel, Figs. 4,6. If a band is not used, this could present problems or damage to the vessel because of the large difference in thermal expansions between the plastic and the graphite or metal. Polypropylene, for example, has a thermal expansion coefficient about 35 times greater than does graphite,

and since the plastic would be constrained by bonding to the graphite, a high stress would be set up. A metal band around such a molded-in bottom, would place both the plastic and graphite in compression, relieving the dangerous tensile stresses. The metal band not only secures the bottom plate firmly to the wall and inner layer in sealed abutment, but its lower edge also protects the plastic from direct contact with the hot plate, and protects much of the graphite periphery. By this design the plastic-walled vessel is virtually as 'unbreakable' as an all-plastic vessel.

The metal ring, or band, may be made of a variety of materials, including the carbon steels, stainless steels and other stainless alloys, aluminum, and others. Metals like the carbon steels may be electroplated or resin coated. The band may be made of solid metal, metal mesh, wire design, and the like. A large variety of metal clamps and fasteners may be used. We found that a solid metal ring firmly secured by shrink fitting is highly satisfactory, simple and economical, and such a ring is preferably used. A small shoulder or ledge at the bottom side of the ring is desirable since it helps secure the plastic edge and protect it. Such a ledge is shown in the drawing as parts 5, 27, 36 and 45 of rings 3, 23, 34 and 44 of Figs. 1-4, respectively.

In fitting the metal ring or band, care must be taken to allow for differences in thermal expansion of the wall and bottom materials over the entire temperature range of the application. For example, if we consider an open ended polypropylene, walled vessel like that of Fig. 1, with an inside diameter of 2.85 in. and an outer diameter of 2.970 in., and a graphite bottom disc of 2.85 in. o.d. which would snug-fit in the i.d. of the plastic vessel, then a type 420 stainless steel ring with an

expansion coefficient of 0.0000059 in./in./°F for use in the temperature application design range (that is with a safety temperature design factor) up to 350°F, would require an i.d. approx. 0.005 in. less than the o.d. (2.970 in.) of the plastic vessel at room temperature. This means that the ring will expand 0.005 in. if it reached a temperature of 350°F. Inasmuch as the ring must keep the plastic and graphite in strong compression, it has to be undersize at room temperature, and heated above 350°F to expand it, in order to shrink fit it on the vessel at room temperature. In use, since the thermal expansion coefficient of graphite is about 1/3 that of stainless steel, and if the ring reached the temperature of 350°F, the graphite would expand about 2 mils, enough to 'sandwich' the expanding plastic against the graphite and the stainless ring with a compressive force great enough to keep the bottom intact and leak proof.

Since the use temperature limit of polypropylene is 275°F (135°C), it should not exceed this temperature for any prolonged period of time. In the practice of this invention, the polypropylene vessels do not exceed this temperature and can operate well below it. For example in an experiment of two weeks duration, 2 polypropylene walled vessels with graphite bottoms and metal rings or bands were assembled with condensers to reflux boiling water on a hot plate. The hot plate temperature was 240 - 260°F and the metal rings at a temperature of 230 - 236°F, as recorded by thermocouples soldered to the rings. Since the plastic is between the ring and the graphite, and since the vessels were filled with boiling water, it was assumed that the polypropylene temperature was no higher than 236°F (115°C) and probably about 10°F below that temperature. Polypropylene walled vessels like the above have also

- operated on hot plates at 375° - 400°F (190-204°C) and above for many hours with ring temperatures not exceeding 275°F (135°C). Since polypropylene walled vessels function excellently on hot plates
- 5 at 375° - 400°F it is apparent that plastic walled vessels made of plastics with higher service temperatures such as polymethylpentene (347°F) (176°C) and fluorinated ethylene propylene (401°F) (204°C) would function well at even higher temperatures.
- 10 This was demonstrated with vessels of our invention where a polymethylpentene walled vessel with a graphite bottom operated for many hours at a hot plate temperature of 450 - 475°F (232° - 246°C) and a ring temperature of about 300°F, (140°C)
- 15 and an FEP (fluorinated ethylene propylene) walled vessel with a graphite bottom operated at a hot plate temperature of 500 - 550°F, (260 - 288°C) and a ring temperature of about 365°F (185°C). Both vessels were below the long time service temperature of
- 20 these polymers.

Example 1 - Polypropylene/FEP-coated
graphite vessel

- An assembled plastic/coated graphite vessel was made and tested as follows. A 250 ml polypropylene
- 25 beaker was placed in a lathe and the bottom machined out, leaving an open ended cylinder. The bottom end was fitted with a graphite disc machined from a porous graphite rod having a bulk density of about 1.72 g/cc. The disc was machined to a thickness of
- 30 0.25 in. and a diameter to conform to the i.d. of the plastic cylinder, in this case 2.85 in. The vessel wall was 0.06 in. thick and 2.970 in. o.d. The graphite was infiltrated with a fluorocarbon resin, in this example, an FEP suspension. The disc
- 35 was infiltrated by placing it in a gasketed metal funnel with a side arm outlet. This was connected

with vacuum tubing to a mechanical vacuum pump, and evacuated from the underside of the disc. The FEP suspension (a DuPont preparation) was fed in from the top until the pores were filled and the suction
5 ceased. The excess resin on the sides was removed, and the disc air dried and cured at 550°F in an electric oven. A coating of the FEP resin was then sprayed over the top side of the infiltrated disc, air dried, and cured at 750°F for 1 hour. The im-
10 pregnated disc with a 2 mil coating was then pressed into the bottom side of the plastic cylinder, with the coated surface facing into the vessel, substantially as shown in Fig. 1, forming a snug fit but not forced. The graphite disc was then firmly secured
15 and sealed by means of a stainless steel band applied by shrink fitting. The band or ring was machined from stainless steel type 420, to an i.d. of 2.965 in. which was .005 in. less than the i.d. of the plastic cylinder (2.970 in.). This represented
20 the expansion of the band to a temperature up to 350°F, well in excess of the temperature it, and the plastic would reach, even at hot plate temperatures of 475 - 500°F. This hot plate temperature is well in excess of our recommended use
25 temperature for polypropylene graphite vessels (350 - 400°F). This assumes that the vessel contains an aqueous fluid and is not allowed to evaporate to dryness. The metal band was 3/8 in. wide and was made with a small shoulder or ledge (5, Fig. 1) to
30 protect the plastic, and most of the graphite periphery, as shown in Fig. 1. In applying the ring to the plastic cylinder with the impregnated graphite disc, the ring was heated in excess of 350°F to allow a fast, easy fit over the o.d. of
35 the cylinder. After the ring was applied, it was immediately cooled in water. The ring was so firmly secured that it, or the graphite bottom, could not

be pushed from the plastic cylinder by hand force. The beaker was then filled with 200 ml of water at 73°F and covered with a watch glass. A conventional griffin-style 250 ml borosilicate beaker was also filled with 200 ml of water (73°F) and covered with a watch glass. Both beakers were placed at ambient room temperature of about 70°F on a rectangular 750 watt flat hot plate which was at a temperature of 400°F as indicated by a surface thermometer.

Both beakers were of approximately the same diameter. Temperature readings of the water in the beakers were made at 1 minute intervals. The beakers were heated to the boiling temperature or until a temperature time equilibrium was established. This procedure was repeated 3 times with 3 similarly prepared sets of beakers. The average of the data obtained were plotted to obtain temperature-time curves 1 and 3 shown in Fig. 7, where curve 1 represents data for fluorinated ethylene propylene, FEP polymer) beaker and curve 3 represents data obtained for the glass beaker. These curves show the significant difference in heating rates of the plastic/graphite vs. glass vessels. Beaker 1 reached the boiling point in 6.5 minutes compared to 24 minutes for beaker 3; the time ratio to reach boiling was 24/6.5 or a heating rate 3.7 times higher for 1 than 3. Since the electrical power supplied to the hot plate is converted into heat, and since the power multiplied by time is a measure of the electrical energy, and therefore heat energy consumed, it is evident that the heat energy consumed in heating the beakers is directly proportional to time. This is shown in the time-temperature curves Fig. 7, where the water filled glass beaker 3, on reaching the boiling point, consumed 3.7 times more heat energy than the plastic/graphite beaker 1.

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The above procedure was again repeated with the same beakers uncovered. The results obtained are shown also in Fig. 7, where curves 2 and 4 are time-temperature curves for the plastic/graphite and glass beakers, respectively. It can be seen that the water in the polypropylene/graphite beaker 2, reached the boiling point in 7 minutes, and the water in the glass beaker did not reach the boiling point even after 40 minutes. Actually the water in the glass beaker reached a maximum temperature of only 204°F after 1 1/2 hours. This shows that water cannot be boiled at an ambient room temperature of 70°F at a hot plate temperature of 375 - 400°F in this type and capacity of widely used commercial vessel. If we select a comparison of time to attain a temperature of 200°F for the two vessels, it can be seen that the time ratio to reach 200°F is 6.2, that is beaker 4 needed 36 minutes vs. 5.8 minutes for beaker 2. This means that 6.2 times more energy was required to heat the water in the glass beaker to 200°F, than the plastic/graphite beaker, to the same temperature both vessels being uncovered.

Example 2 - Polymethylpentene/graphite Vessel

25 An assembled plastic/graphite vessel was made and tested as follows. A commercial polymethylpentene beaker of 250 ml capacity was placed in a lathe and the bottom machined out. The bottom end of the resulting cylinder was fitted with a graphite disc machined from porous graphite rod of a bulk density of 1.76 g/cc. The disc was 0.25 in. thick and of a diameter to conform to the i.d. of the beaker, in this case 2.67 in. The vessel wall was 0.05 in. thick and 2.77 in. o.d. Although the graphite material had a porosity of about 10 vol. percent, it was not infiltrated, since testing showed that it did not appreciably absorb water unless it was

pressurized. This was demonstrated by heating the disc to 400°F on a hot plate for 15 minutes and weighing it after cooling. No weight change was shown from a previous room temperature weighing.

5 The disc was then immersed in hot soapy water for 15 minutes, rinsed, and towel dried. Upon weighing again, no weight change was shown to the nearest 0.10 gram. One side of the graphite disc, that would serve as the internal bottom side of the

10 vessel, or what may also be called the service side, was coated with a 2 mil thick film of polychlorotrifluoroethylene by molding. This was accomplished in a mechanical lever press at a pressure of about 1000 psig and a temperature of about 500-550°F

15 causing the film to be strongly bonded to the graphite. The coated disc was then hand pressed into the bottom end of the cylinder forming a snug fit, but not forced to form a plastic walled vessel substantially as shown in Fig. 1. The graphite disc was firmly secured by means

20 of a carbon steel ring or band applied by shrink fitting. The band was machined to an i.d. of 2.763 in., which was 0.007 in. less than the o.d. of the plastic cylinder (2.770 in. at room temperature). This difference in inner and outer diameters (0.007 in.)

25 represents the expansion of the band to a temperature up to about 422°F, well within the temperature the band and the plastic would reach, even at hot plate temperatures of 500 to 550°F. This hot plate temperature is well in excess of our recommended use temperature for polymethylpentene vessels (450-475°F). This

30 assumes that the vessel contain an aqueous or similar fluid and is not allowed to evaporate to dryness. The metal band was 3/8 in. wide and was made with a small shoulder or ledge (element 3 of Fig. 1) to

35 protect the plastic, and most of the graphite discs periphery. The ring was applied as described in

Example 1 except that the temperature to which the

ring was heated was in excess of 422°F.

Three polymethyl pentene/graphite and three new glass beakers were evaluated in accordance with the time-temperature heating tests procedure described in example 1. The results obtained are shown by the temperature-time curves in Fig. 8. In Fig. 8 curve 1 represents data for polymethyl-pentene/graphite, and curve 2 represents data for glass. Each beaker contained 200 ml of water, and was covered. The hot plate temperature was 475-500°F. The water in the polymethylpentene/graphite beaker reached boiling in 7 minutes compared to 22 minutes for the glass beaker. The ratio of 3.1 indicates that 3.1 times as much heat energy was required to heat the water in the glass vessel 2, to boiling, as compared to the polymethylpentene/graphite beaker.

Example 3 - Polypropylene coated impervious graphite vessel

An assembled plastic/coated Karbate vessel was made and tested as follows: A commercial polypropylene beaker of 250 ml capacity, was placed in a lathe and the bottom machined out. The bottom end of the plastic beaker was fitted with an impervious graphite disc ('Karbate', a Union Carbide Corp. product), cut and machined from a rectangular piece of the material. The disc was 0.25 in. thick and of a diameter to conform to the i.d. of the polypropylene beaker, in this case 2.85 in. (as in example 1). The plastic wall was 0.06 in. thick and 2.970 in. o.d. A polypropylene (PP) film 0.005 in. was molded to the service side of the disc as described in example 2, except that the molding temperature was about 400°F. The coated disc was secured to the vessel with a shrink fit aluminum band about 1/16 in. thick and 3/8 in. wide, with a narrow shoulder on the bottom side substantially as described in

examples 1, and 2, and shown in Fig. 1. Since the ring was aluminum, with a coefficient of thermal expansion of $13.5 \times 10^{-6}/\text{in.}/\text{in.}/^{\circ}\text{F}$, allowance had to be made for the higher expansion, i.e. 0.0112 in. in the temperature range 350°F . The ring was applied in accordance with the method described in example 1. The novel beaker was capable of applications as a vessel in the same temperature range as the polypropylene beaker in example 1.

Three such polypropylene/graphite, and three glass beakers were evaluated in accordance with the procedure used in examples 1 and 2, and the results are shown in Fig. 9, wherein curve 1 is for polypropylene/PP coated graphite, and curve 2 is for glass. The beakers contained 200 ml of water and were covered. The hot plate temperature was $240-260^{\circ}\text{F}$. The water in novel beakers reached the boiling point in 20 minutes as compared to 38 minutes for water in the glass beakers to reach a temperature of 160°F . With continued heating, the water in the glass beakers reached an equilibrium temperature of $178-180^{\circ}\text{F}$ after 2 hours of heating as will be described in the next example 4. This temperature was not exceeded after 2 weeks (336 hours) of continuous heating at $240-260^{\circ}\text{F}$. Fig. 9 shows that the water in the polypropylene/PP-coated graphite beaker (1) Reached the temperature of 160°R in 7.8 min. as compared to 38 minutes for water in the glass beaker(2), or a ratio of $38/7.8 = 4.9$. Thus heating water in the glass beaker required 4.9 times as much energy as that required in the plastic/graphite beaker (1). The relatively low hot plate temperature of 250°F used to boil water in the plastic/PP coated graphite beaker

represents a difference of only 38°F (21°C) between the hot plate and the boiling water. Hot plates operating at this temperature would be highly energy saving for many applications.

5 Example 4 - Reflux heating of water in
Polypropylene/PP-coated
Graphite Vessel

10 The open ends of the novel beakers made
as described in example 3 were fitted with gaskets
and covers and connected to refluxing condensers.

With 200 ml of water in two of the polypropylene/PP coated graphite beakers, and the same in two glass beakers, all the beakers were heated on a hot plate at 240-260°F. After 18 to 20 minutes of heating, the water was boiling in the novel beakers. The water in the glass beakers at this time was only at a temperature of 160°F, (see Fig. 9). Heating was continuous for 2 weeks (336 hours) with the water in the glass beakers reaching a maximum temperature of 178-180°F. This equilibrium temperature was reached in about 2 hours and remained so during the entire period. The temperature of the aluminum bands on the novel beakers stabilized at 230-236°F.

Examination of the novel polypropylene/PP-coated graphite beakers after testing showed them to be in excellent condition.

Example 5 - Borosilicate glass/PP-coated Graphite Vessel

A borosilicate glass/PP-coated graphite vessel substantially like that shown in Fig. 2 of the drawing was prepared and tested as follows. A borosilicate glass beaker of 250 ml capacity was carefully fixtured and mounted on a diamond cut-off wheel machine and the bottom cut off. The cut surface was then carefully ground to a smooth finish and fitted with a graphite disc gasketed with flexible graphite ('Grafoil' Union Carbide Product). It was snugly fit with finger pressure, with the gasket (24, Fig. 2) compensating for the dimensional variations in the i.d. of the glass. The graphite, of bulk density 1.76 g/cc, had an expansion coefficient the same as the glass (1.8×10^{-6} in./in./°F.) The graphite (22, Fig. 2) was secured to the glass cylinder with a stainless steel type 420 band 23 of the type described in Example 1. A flexible

graphite, external gasket 25 between the glass and metal ring compensated for the dimensional variations of the glass cylinder o.d. The ring was fitted as described in Example 1, allowing for expansion to 350°F. The graphite disc 22 with a bulk density of 1.76, the same type used in example 2, was coated with a 0.005 in. thick film of polypropylene 26 by molding, as described in example 2, and 3. Three glass/PP-coated graphite beakers and three all-glass beakers were filled with 150 ml water, covered and evaluated as in the previous examples. In this example, the hot plate temperature was 290-310°F. The curves in Fig. 10, shows that the glass/PP-coated graphite beakers, curve I, reached the boiling point in 5 minutes compared to the glass beakers, curve 2, which reached a maximum temperature of 190°F after 40 minutes. The glass beakers did not reach the boiling point after an hour and stabilized at an equilibrium temperature of 204-206°F. Comparing the heating times to reach a temperature of 190°F, one obtains a ratio of 34 minutes (glass beakers) and 4.2 minutes (novel beakers) or $34/4.2=8.1$. Thus it required over 8 times the energy to heat the water in the all-glass beakers to 190°F as it did the glass/PP-coated graphite beakers.

Example 6

A polypropylene beaker, fitted with an impervious graphite ('Karbete') disc, secured with a type 304 stainless steel ring of expansion 0.0074 to 350°F (177°C) was prepared and evaluated in accordance with the previous examples. The results are shown in Fig. 11, for the covered beakers heated at 340°F (171°C) on a hot plate at a ratio of 40 minutes (2) 9 minutes(1) = 4.4, it can be seen that the glass beaker requires 4.4 times the energy of the plastic/graphite beaker to heat water to the boiling point.

Example 7

A polymethylpentene ("pentene") beaker, fitted with a graphite disc of bulk density 1.76 g/cc, to which was molded a 2 mil thick PCTFE film, and secured with type 420 stainless steel ring, was prepared and evaluated in accordance with the previous examples. The results are shown in Fig. 12, for covered beakers heated on a hot plate at 480-500°F. (240-260°C). It can be seen that the glass beaker 2, requires 18.5 minutes to reach the boiling point of water, and the pentene/coated graphite only 4.5 minutes. This gives a ratio of $18.5/4.5 = 4.1$, demonstrating that the water in the glass beaker requires over 4 times more energy to reach the boiling point, than the water in the plastic/coated graphite beaker.

Example 8

Two vessels of approximately 2500 ml capacity each were tested: (1) a polypentene plastic vessel fitted with a graphite bottom element and (2) a conventional glass vessel were evaluated in a similar manner to the vessels in the previous examples by heating on a hot plate at a temperature of 480-500°F. (249-260°C). Both vessels were covered. The graphite disc, and metal band, and the method of preparation of (1) were the same as that described in example 7, except for the diameter which was approximately 4 in. The results showed that the glass vessel with 2000 ml of water required 67 minutes to reach the boiling point whereas the water in the pentene/graphite vessel (also 2000 ml) required only 14.6 minutes to reach boiling. The ratio of $67/14.6 = 4.6$ again showed the significant energy savings. In this case $1/4.6$ of the energy required to heat the water in the glass vessel.

Example 9

A polypropylene beaker fitted with an aluminum alloy (6061) disc 0.125 in. thick, to which was molded a 0.003 in. thick PCTFE film was prepared in accordance with example 7, dealing with 250 ml beakers. The evaluation was also in accordance with previous examples. Thus the polypropylene/coated aluminum, and glass beakers each were filled with 200 ml of water at 72°F, (22.2°C) covered and placed on a hot plate at 375-400°F. The water in the polypropylene beaker with the coated aluminum bottom boiled in 7 1/2 minutes compared to 29 minutes for water in the glass beaker, or a ratio of $29/7.5 = 3.9$. Thus the plastic-aluminum beaker used only about 1/4 of the energy required by the glass beaker.

Example 10

Part A

A 250 ml polypropylene beaker with a FEP-coated graphite bottom, element of the same type described in example 1, was filled with 200 ml of water at 70°F, covered with a watch glass, and placed on a hot plate at a surface temperature of 600°F. (316°C). The water in the beaker came to a vigorous but smooth boil in 3 minutes. This is shown in Table II which gives hot plate temperatures, water temperatures, and time. Note that no warping of the graphite bottom occurs, even after repeated heating and cooling cycles.

TABLE II
Hot Plate Temperature Vs Time to Boil
Water in Polypropylene/FEP-
Coated Graphite Beaker

Time Min.	Hot Plate Temperature		Water Temperature	
	^o F	^o C	^o F	^o C
0	600	316	70	21
1	580	304	118	48
2	565	296	170	77
3	550	288	212	100

(vigorous boil)

Although the hot plate temperatures shown in Table II are well in excess of the recommended 400^oF (204^oC) temperature for polypropylene/graphite or polypropylene/aluminum beakers, it illustrates the broad hot plate temperature range in which these vessels can operate.

Part B

Table III shows the time, hot plate temperatures and water temperatures of an all glass 250 ml beaker, filled with 200 ml of water, covered with a watch glass, and placed on the same hot plate as used at a surface temperature of 600^oF (316^oC).

TABLE III
Hot Plate Temperature Vs Time to Boil
Water in Glass Beaker

Time Min.	Hot Plate Temperature		Water Temperature	
	$^{\circ}\text{F}$	$^{\circ}\text{C}$	$^{\circ}\text{F}$	$^{\circ}\text{C}$
0	605	319	70	21.1
1	600	316	84	28.9
2	593	313	100	38
3	598	315	116	41
4	608	319	130	54
5	608	319	143	62
7	570	299	167	75
8	550	288	178	78
9	540	282	187	86
10	545	286	196	92
11	560	293	205	96
11.75	574	301	211	99.9

(weak boil)

20 From the data in Tables II and III, it is seen that,
 as in previous examples, a large energy savings is
 evident, since it requires about four times longer to
 boil water in a glass beaker compared to our plastic/
 coated graphite vessel. The ratio, plastic/coated
 25 graphite 3 min/glass 11.75 min. = 0.255, indicates
 that only 1/4 the energy is required to boil water
 in the polypropylene/coated graphite beaker,
 compared to the all-glass beaker. Bumping was quite
 in evidence in the glass beaker, as compared to the
 30 very smooth boil of our energy saving beaker.

1 CLAIMS:

1. An energy-efficient heating vessel having thermally-insulative sidewalls of a plastics material and a thermally-conductive bottom, wherein the vessel

5 bottom includes:

an inner layer of plastics material, providing minimal resistance to heat transfer therethrough, the thinness of the layer being limited only by the requirement that it be liquid-impervious, and

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an outer layer of thermally-conductive graphitic material in thermal contact with and supporting the inner layer, for thermal contact with a heating surface,

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whereby the vessel, in use, serves to transmit heat from such heating surface through the bottom to the contents of the vessel and to retard the transfer of heat from the contents through the sidewalls.

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2. A vessel according to claim 1, in which the inner layer is of the same material as the sidewalls and is continuous therewith.

3. A vessel according to claim 1 or 2, in which the inner layer comprises a thermoplastic material.

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4. A vessel according to any preceding claim, in which the outer layer is bonded to the inner layer.

5. A vessel according to any preceding claim, wherein the inner layer has a thickness of 0.025 to 0.25 mm (1 to 10 mils).

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6. A vessel according to any preceding claim, wherein the outer layer has a thickness of at least 3 mm (1/8").

7. An energy-saving beaker comprising a vessel according to any preceding claim.

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8. An energy-saving flask comprising a vessel



1 according to any of claims 1 to 6.

9. An energy-saving water-heating tank
comprising a vessel according to any of claims 1 to 6.

5 10. An energy-saving still comprising a vessel
according to any of claims 1 to 6.

11. Energy-saving cookware comprising one or more
vessels according to any of claims 1 to 6.

12. An energy-saving heating vessel according to
claim 1, substantially as described with reference to the
10 accompanying drawings.

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