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SPECIFICATION

5 **SYSTEM FOR MONITORING WATER CONSUMING STRUCTURES
AND THEIR HEAT USE IN AN INDIVIDUAL UNIT OF A MULTI-
UNIT BUILDING AND A SYSTEM FOR BILLING THEREFOR**

BACKGROUND OF THE INVENTION

10 The present invention relates to a system for
monitoring the water consumption and energy use of
water consuming devices and monitoring the energy use
of water operated heating and cooling devices in
multi-unit building complexes where the individual
units are supplied water from a common source and
more particularly to a system which will calculate
the water consumption and water related energy use of
15 the individual units so that water, sewer and energy
costs can be fairly apportioned to the units to
encourage conservation. The invention also relates
to monitoring unusual water usage to detect leaks and
open valves.

20 **SUMMARY AND OBJECTS OF THE INVENTION**

25 The individual units of a multi-unit building
such as an apartment building are supplied water from
a common source (the outlet of the building water
meter). The water inlet is split into hot and cold
water lines with the hot water line passing through
a heater (typically there are separate hot water and
heating boilers) which heat the water to the required
temperature. In conventional construction, multiple
vertical risers supply stacked bathrooms, kitchens
30 and heating/cooling devices. As a result the water
supplied to an individual unit can not be metered
without substantial, very costly, plumbing
infrastructure changes.

35 It is an object of the present invention to
measure the water consumption and the water heat



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energy use in an individual unit in a multi-unit building so that the individual unit can be assigned responsibility therefor without substantial plumbing infrastructure changes.

5 It is another object of the present invention to monitor the condition of a water consuming structure so that leaks can be serviced and erroneously open lines can be closed.

BRIEF DESCRIPTION OF THE DRAWINGS

Referring to the drawings:

Figure 1 is a schematic illustration of the water consuming devices of a four unit apartment building wherein each unit has a bathroom with a sink (including any associated tub/shower) and a toilet and a kitchen with a sink (including associated appliances such as a dishwasher) and wherein each pipe supplying the water consuming devices includes a monitor made in accordance with the teachings of the present invention;

Figure 2 is a schematic illustration of the heating/cooling system for the same apartment building wherein each apartment has one or more heating/cooling devices each having upstream and downstream monitors, one monitoring temperature and volumetric flow and the other monitoring temperature;

Figure 3 is a schematic illustration of a monitor shown in figures 1-2;

Figure 4 is a logic diagram for the volume/temperature functions of a monitor;

Figure 5 is a logic diagram for a monitor which will issue an alarm signal when the water using device is continuously open;

Figure 6 is a schematic illustration of a system for a multi story building including a receiver on each floor for receiving and outputting data from the

monitors on its floor;

Figure 7 is a logic diagram for a monitor which will issue a maintenance signal when a water device is leaking;

5 Figure 8 is a schematic illustration for a home system;

Figure 9 is a logic diagram for comparing the output of a common monitor with the outputs of all the dedicated monitors to identify a leak;

10 Figure 10 is a schematic illustration of a system for a building that has a plurality of local receivers that are hard wired in series with the base local receiver outputting data;

Figure 11 is a schematic illustration of a system similar to that of figure 6, with individual local receivers hard wired or phone linked in parallel to a base local computer;

15 Figure 12 is a schematic illustration of a system having a plurality of local receivers linked in series or in parallel to a remote receiver; and

20 Figure 13 is a schematic illustration of a system having a plurality of local and remote receivers which are linked to a data base.

DESCRIPTION OF THE PREFERRED EMBODIMENT

25 Utility provided water 10 (fig. 1) generally is metered by a water meter WM 11 as it enters a building such as an apartment house or office building. A portion of the water branches off to supply the building cold water supply line 12 and the
30 other portion is supplied to a hot water heater H 13 which supplies the hot water supply line 14 of the building. The building has a number of similar units (in a two story apartment house, there could be four one bedroom apartments, two on each floor, for
35 example) each having a sink (including associated tub/shower) and toilet in the powder room and a

second sink (including any associated appliances such as a dishwasher) in the kitchen. Each sink is supplied by separate hot and cold water lines (the hot and cold water lines of the kitchen sink may also supply a dishwasher) and each toilet is supplied by a single cold water line. Stacked kitchens and bathrooms are supplied via vertical risers 15. In each water line (or just downstream in the mixed water line) is located a monitor M 19. Figure 2 shows the heating/cooling system for the same units. Water (hot in the winter or cold in the summer) is supplied by a suitable source such as a heat pump HP 13A (discrete sources such as a boiler for hot water and a chiller for cold water could be utilized) to a feed line 16 which supplies the individual heating or cooling units H/C 23 through multiple vertical risers 17. The water is returned to the source HP by suitable return lines 18. Located upstream and downstream of each heating or cooling unit H/C is a monitor M.

A monitor M (fig. 3) which can be located in each line by a plumber, is a unitary battery operated structure, which is fully sealed to reduce tampering and water damage. The monitor can have a universal set of fittings to simplify installation. A monitor may include a pipe 20 in which may be permanently secured a gearbox 21 such as the type found in lawn sprinkler heads to control the movement of the water spray. The gear box has axial input 22 and output 24 shafts which are connected to a turbine wheel drive propeller 26 and a copper or other metal axially extending partial cylindrical portion paddle wheel 28. Water entering the pipe, passes through a set of orifices 30 which direct the water at the propeller blades thereby efficiently driving the gearbox. The gear ratio of the gearbox is selected so that the partial cylindrical portion 28 will make no more than

about half a rotation during a sampling time (a rate of rotation that will assure that an oscillator (OSC - 25) will sense the presence of the partial cylindrical portion (the target) 28 twice each revolution). The gear ratio may be different for different devices (full flow for a toilet is very different than full flow for a tub, for example). Coil 29 will change inductance twice each revolution changing the frequency of the oscillator. The microprocessor uc 31 or custom specialized electronic circuit can therefore count a pulse each time the target 28 is located at 0° and 180° and each pulse equates to a unit volume of liquid. Referring to figure 4, if a reading is to be taken approximately once per "X" time (a minute, for example) based on a timer circuit 33 associated with the microprocessor (see figure 3), the gear ratio will be selected so that the target will rotate less than 180° , during one minute with maximum flow through the pipe. Alternately, other sensors could be used such as a rotating magnet and Hall effect sensor, reed switch, capacitive sensor, optical sensor, inductive sensor with ferrite rotator, etc. When, during that time interval, the target has been sensed, a volume counter will be updated to a new total of volume units and at some other regular time interval "y" (once a day, for example), the total volume count will be transmitted by the radio transmitter 34. The updated count is representative of the total volumetric flow through the pipe. Limiting the rate of rotation of the target with the gear box so that a reading need only be taken once per minute, prolongs battery life since the microprocessor uc only has to be turned on once per minute. The flow measuring system could also be an ultrasonic Doppler flowmeter, a magnetic flowmeter, an electronic mass flowmeter, or a vortex flowmeter, for example.

The energy use of the hot water used in a water using device may be computed by multiplying the volumetric volume of the associated hot water pipe by the temperature that hot water is supplied where the monitor is receiving hot water from the hot water heater. Optionally, the monitor can include a heat thermistor 32 (or a thermocouple, etc.) attached to the pipe to sense the temperature of the fluid flowing through the monitor. The microprocessor uc 31 may multiply the temperature by that unit volumetric flow to define a heat content number (BTU use - figure 4) and will then update the total heat content totalizator. By subtracting the total heat count at one side of a heating/cooling unit H/C from the simultaneous total heat count at the other side (the subtraction made by a local receiver which receives the data from both monitors - Figure 7, for example), the energy use of the heating/cooling unit can be determined. Alternately, one of the monitors on either side of a heating/ cooling unit can monitor only temperature and be connected to the other monitor with that monitor making both computations such as by subtracting out the temperature reading from the other to compute the heat change. Should electrical power be available or should the battery economics permit, the position of the target could be sampled continuously and the gear box would not be required.

Once every day (or some other time interval) which equates to "Y" time interval, the microprocessor will operate the transmitter (which is a radio transmitter 33 in the preferred embodiment but could be an ultra sonic or infrared transmitter, etc.) to transmit the then current count of the register which is representative of volumetric flow, the then current total of the heat content totalizator, identifier data which identifies the apartment

unit, the water using device, etc. and any pulse count data used to chronologically locate the transmission.

5 The microprocessor uc can also determine that a
water consuming device has been left open (a tub
running continuously, for example). For example,
the microprocessor should detect the presence of the
target once a minute while the tub is being filled at
the fully open condition. Even at a slow fill rate
10 the target should be sensed once every "X" minutes
(figure 5). If "X" is five minutes, for example, the
filling process should be complete within twenty
minutes (four multiples of "X"). Accordingly,
according to the algorithm expressed in figure 5,
15 when the water has been running for "X" minutes and
the target has been sensed, the counter is
incremented and the process is repeated. When the
target has been sensed in the next "X" minutes the
counter again increments and so forth. If the count
20 reaches 15 ("Y"), for example, the water has run for
a time beyond that which was required to fill the tub
and this can mean that someone has failed to turn the
water off, etc. Should the microprocessor determine
that flow has continued for more "Y" increments of
25 "X", the microprocessor will direct the transmitter
to transmit an alarm signal, identifying the water
consuming device, to the receiver which indicates
that the device has been left open so that immediate
action can be taken to correct the problem. The
30 alarm signal can be transmitted to a local receiver
which could be a general alarm system for the home
which would announce the condition or it could be
further transmitted to a remote receiver which could
be at a home security company which could take
35 appropriate action or it could be a part of the water
usage system for a multiple unit building as
described herein. This algorithm can also be

will issue a maintenance signal.

5 The receiver, in its simplest form, could
contain an information system (or a part of a larger
information system) for an individual unit or a home
(figure 8). A monitor which would not have to
10 monitor temperature, could be placed in each line
supplying the water consuming devices so that
volumetric flow data could be transmitted to a local
receiver which would determine whether any device was
15 leaking or open and would issue an appropriate alarm
or maintenance signal for that device. This figure
also illustrates a monitor downstream of the water
meter WM - 11. This monitor can implement the
algorithm of figure 5 to detect a break in any
20 downstream water line such as could happen as a
result of earthquake or freeze damage, for example.
By comparing the volumetric flow/unit of time of this
common monitor (figure 9), with the total/unit of
time of all the dedicated monitors, an internal leak
25 can be identified (a variance of X% would indicate an
internal leak). Maintenance and alarm signals can be
issued by the local receiver and optionally the local
receiver can communicate with a remote receiver in
the form of a security company or to the monitoring
or billing system to obtain assistance..

As shown in figure 10, the multi-unit building
may have a plurality of local receivers hard wired in
series (or connected on a phone line) to a base local
receiver (the local receiver located on the
30 superintendents' floor for example), with the base
local receiver presenting the data for all the local
receivers. Instead of phone lines or wires, a radio
(custom or PCS system) could transmit the data from
one local receiver to other local/remote receivers.
35 The total volumetric flow and energy use for an
individual unit can be computed by each of the local
receivers or all computations can be performed by the

base local receiver. Alternately, such a base local receiver can be connected in parallel with the other local receivers (figure 11). The base receiver may not receive data from a monitor but only receive data from local receivers (receivers receiving data from monitors (figure 12)). The base receiver is then a remote receiver. The remote receiver (figure 13) can provide a database which communicates via phone lines with any number of local and/or remote receivers and a receiver (a local receiver, a base local receiver or a remote receiver) can operate on the data and prepare, bills for water, energy and sewer use for each reporting unit which can be sent directly to the individual units or to the buildings for distribution as well as support reporting of leaks and open faucets, etc.

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What Is Claimed Is:

1. A system for monitoring the use of water in at least one individual unit of a multi-unit building wherein the multi-unit building is supplied water from a common source and said individual unit has a plurality of water consuming structures each supplied by one or a pair of water pipes supplied from said common source, comprising
 - a monitor for monitoring the volumetric flow through each of said water pipes, each of said monitors including
 - means for determining the volumetric flow through the pipe, and
 - means for periodically transmitting a signal encoded with the volumetric flow of the pipe and the identification of the individual unit in which the pipe is located,
 - remote receiver means for receiving the encoded signals from each of said monitors and computing a total volumetric flow of water for said individual unit for a selected period of time.
2. A system for monitoring the use of water in at least one individual unit of a multi-unit building according to claim 1, wherein said remote receiver means comprises
 - a first remote receiver for receiving the encoded signals from each of said monitors and periodically transmitting volumetric flow data for said monitors, and
 - a second remote receiver for receiving the volumetric flow data from said first remote receiver and presenting the total volumetric flow for said individual unit.

3. A system for monitoring the use of water in at least one individual unit of a multi-unit building according to claim 1, wherein said transmitting means comprises an RF transmitter.

5 4. A system for monitoring the use of water in at least one individual unit of a multi-unit building according to claim 2,

wherein said first remote receiver comprises

10 an RF receiver for receiving the encoded signals transmitted from each of said monitors and

telephone means for transmitting the volumetric flow data for said monitors, and

15 wherein said second remote receiver comprises telephone means for receiving the volumetric flow data transmitted by said first remote receiver telephone means.

20 5. A system for monitoring the use of water in at least one individual unit of a multi-unit building according to claim 2, wherein said first remote receiver comprises means for computing a total volumetric flow for said individual unit and said periodically transmitted volumetric flow data for
25 said individual unit comprises said total volumetric flow for said individual unit.

30 6. A system for monitoring the use of water in at least one individual unit of a multi-unit building according to claim 2, wherein said periodically transmitted volumetric flow data comprises the volumetric flow for each of said monitors and said second remote receiver comprises means for computing a total volumetric flow for an individual unit from said transmitted volumetric flow data.

7. A system for monitoring the use of water in at least one individual unit of a multi-unit building according to claim 2, wherein said means for determining the volumetric flow through the pipe
5 comprises a turbine flow meter.
8. A system for monitoring the use of water in at least one individual unit of a multi-unit building according to claim 2, wherein said means for determining the volumetric flow through the pipe
10 comprises a vortex flow meter.
9. A system for monitoring the use of water in at least one individual unit of a multi-unit building wherein the multi-unit building according to claim 1 wherein a plurality of individual units is monitored.
- 15 10. A system for monitoring the use of water in an individual unit of a multi-unit building according to claim 9, wherein said first remote receiver comprises means for computing a total volumetric flow for each of said plurality of individual units and wherein
20 said total volumetric flow for each of said plurality of individual units comprises said volumetric flow data.
- 25 11. A system for monitoring the use of water in an individual unit of a multi-unit building according to claim 10, wherein said volumetric flow data comprises the volumetric flow for each of said monitors and said second remote receiver comprises means for computing a total volumetric flow for each of said individual units.
- 30 12. A system for monitoring the use of water in an individual unit of a multi-unit building according to claim 9, wherein said means for determining the

volumetric flow through the pipe comprises a turbine flow meter.

13. A system for monitoring the use of water in an individual unit of a multi-unit building according to claim 9, wherein said means for determining the volumetric flow through the pipe comprises a vortex flow meter.

14. A system for monitoring a water consuming structure supplied by a water pipe comprising means for determining that volumetric flow through the pipe has been continuous during a predetermined period of time,

said predetermined time being selected to be greater than a period of time during which water should be flowing continuously through said pipe, and

means for transmitting an alarm signal in the event that it is determined that flow to said water consuming structure has been continuous for said predetermined time.

15. A system for monitoring a water consuming structure according to claim 14, further comprising remote receiver means for receiving said signal and presenting the signal, so that corrective action can be taken.

16. A system for monitoring a water consuming structure according to claim 15, wherein said remote receiver means comprises

first remote receiver means for receiving and retransmitting the signal, and

second remote receiver means for receiving the retransmitted signal from said first remote receiver means and presenting said signal so that

corrective action can be taken.

17. A system for monitoring a water consuming structure according to claim 14, wherein said transmitting means comprises an RF transmitter.

5 18. A system for monitoring a water consuming structure according to claim 16,

wherein said first remote receiver for receiving and retransmitting the alarm signal comprises

10 an RF receiver for receiving the alarm signal transmitted from said transmitting means and telephone means for retransmitting the signal and

15 wherein said second remote receiver comprises telephone receiver means.

19. A system for monitoring water flow in a building having water using structures supplied from a common pipe, comprising

20 means for determining that volumetric flow through the pipe has been continuous during a predetermined period of time,

25 said predetermined time being selected to be greater than a period of time during which water should be flowing continuously through said pipe, and

means for transmitting an alarm signal in the event that it is determined that flow in said common pipe has been continuous for said predetermined time.

30 20. A system for monitoring water flow in a building having water using structures according to claim 19, further comprising

remote receiver means for receiving said

signal and presenting the signal, so that corrective action can be taken.

21. A system for monitoring water flow in a building having water using structures according to claim 20, wherein said remote receiver means comprises
5 first remote receiver means for receiving and retransmitting the signal, and
second remote receiver means for receiving the retransmitted signal from said first remote receiver means and presenting said signal so that
10 corrective action can be taken.

22. A system for monitoring water flow in a building having water using structures according to claim 19, wherein said transmitting means comprises an RF transmitter.
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23. A system for monitoring water flow in a building having water using structures according to claim 21, wherein said first remote receiver for receiving and retransmitting the alarm signal comprises
20 an RF receiver for receiving the alarm signal transmitted from said transmitting means and telephone means for retransmitting the signal and
25 wherein said second remote receiver comprises telephone receiver means.

24. A system for monitoring a water consuming structure supplied by a water pipe comprising
means for determining the current
30 volumetric flow through the pipe during a predetermined period of time,
means for comparing the determined volumetric flow for said predetermined period of time

with a reference volumetric flow for said same predetermined period of time, and

5 means for transmitting a maintenance signal in the event that said determined current volumetric flow during said predetermined period of time exceeds said reference volumetric flow for said same predetermined period of time by a selected amount.

10 25. A system for monitoring a water consuming structure according to claim 24, further comprising remote receiver means for receiving said maintenance signal and presenting the maintenance signal, so that corrective action can be taken.

15 26. A system for monitoring a water consuming structure according to claim 25, wherein said remote receiver means comprises

first remote receiver means for receiving and retransmitting the maintenance signal, and
20 second remote receiver means for receiving the retransmitted maintenance signal from said first remote receiver means and presenting said maintenance signal so that corrective action can be taken.

25 27. A system for monitoring a water consuming structure according to claim 24, wherein said transmitting means comprises an RF transmitter.

28. A system for monitoring a water consuming structure according to claim 26,

30 wherein said first remote receiver for receiving and retransmitting the maintenance signal comprises

an RF receiver for receiving the maintenance signal transmitted from said transmitting means and

telephone means for retransmitting the maintenance signal and

wherein said second remote receiver comprises telephone receiver means.

5 29. A system for monitoring a water consuming structure according to claim 24, wherein said reference volumetric flow is a rolling volumetric flow average.

10 30. A system for monitoring a water consuming structure according to claim 24, wherein said reference volumetric flow is a standard volumetric flow average.

15 31. A system for monitoring the use of heat energy in water devices in an individual unit of a multi-unit building wherein the multi-unit building is supplied water from a common source and said individual unit has a plurality of energy consuming water devices each supplied by a water pipe supplied from said common source comprising

20 monitor means for monitoring the flow through each of said water pipes, each of said monitor means including

means for determining that successive volumetric flow units have flowed through said pipe,

25 means for defining the heat energy of each of said successive volumetric flow units,

means for computing a total heat energy for said successive volumetric flow units, and

30 means for periodically transmitting said total heat energy for said successive volumetric flow units, and

remote receiver means for receiving said total heat energy transmitted from each of said

plurality of monitors and computing a total heat energy use for said individual unit for a selected period of time.

5 32. A system for monitoring the use of heat energy in water devices in an individual unit of a multi-unit building according to claim 31, wherein said plurality of energy consuming water devices includes at least one hot water consuming device supplied by a hot water pipe, and wherein said monitor means
10 comprises a single monitor.

15 33. A system for monitoring the use of heat energy in water devices in an individual unit of a multi-unit building according to claim 31, wherein said plurality of energy consuming water devices includes at least one heating/cooling device supplied by a water pipe, and wherein said monitor means comprises a monitor on either side of said heating/cooling device and said remote receiver means computes a total heat energy use for each heating/cooling device
20 by subtracting the total heat energy of one of said monitors from the total heat energy of the other of said monitors.

25 34. A system for monitoring the use of heat energy in water devices in an individual unit of a multi-unit building according to claim 32, wherein said plurality of energy consuming water devices includes at least one heating/cooling device supplied by a water pipe, and wherein said monitor means comprises a first monitor on one side of said heating/cooling device for determining the temperature of the water
30 and a second monitor for determining the volumetric flow through the pipe, and determining the temperature of the water, said second monitor connected to said first monitor and further including

means for computing a total energy use of each of said successive volumetric flow units by differencing the temperatures of said first and second monitors.

5 35. A system for monitoring the use of heat energy in water devices in an individual unit of a multi-unit building according to claim 34, wherein said remote receiver means comprises

10 a first remote receiver for receiving the total heat energy from each of said monitors and periodically retransmitting heat energy data for said monitors, and

15 a second remote receiver for receiving the heat energy data from said first remote receiver and presenting the total heat energy of the hot water for said individual unit .

20 36. A system for monitoring the use of heat energy in water devices in an individual unit of a multi-unit building according to claim 35, wherein said first remote receiver comprises means for calculating the total heat energy of the hot water for said individual unit for a selected period of time and said total heat energy for the individual unit comprises the heat energy data transmitted from said first remote receiver to said second remote receiver.

25 37. A system for monitoring the use of heat energy in water devices in an individual unit of a multi-unit building according to claim 35, wherein said second remote receiver comprises means for calculating the total heat energy of the hot water for said individual unit for a selected period of time and said total heat energy for each monitor comprises the heat energy data transmitted from said first remote receiver to said second remote receiver.

38. A system for an individual unit of a multi-unit building for water use wherein the multi-unit building is supplied water from a common source and said individual unit has a plurality of water
5 consuming structures each supplied by one or a pair of water pipes supplied from said common source, comprising

a monitor for monitoring the volumetric flow through each of said water pipes supplying each
10 of said water consuming devices, each of said monitors including

means for determining the volumetric flow through the pipe, and

means for periodically transmitting a
15 signal encoded with the volumetric flow of the pipe and the identification of the individual unit in which the pipe is located,

remote receiver means for

receiving the encoded signals from
20 each of said monitors,

defining a total volumetric flow of water for said individual unit for a selected period of time, and

computing a water consumption charge
25 for said total volumetric flow of water.

39. A system according to claim 38, further comprising means for preparing a bill to the individual unit for said water consumption charge.

40. A system according to claim 38, further
30 comprising means for forwarding said bill to the individual unit for said water consumption charge.

41. A system according to claim 38, wherein said water consumption charge includes water and sewer costs.

42. A system according to claim 38, wherein said remote receiver means comprises

5 a first remote receiver for receiving the encoded signals from each of said monitors and periodically transmitting volumetric flow data for said monitors, and

10 a second remote receiver for receiving the volumetric flow data from said first remote receiver, said second remote receiver comprising said means for computing a water consumption charge and said means for preparing and forwarding said bill.

43. A system according to claim 38, wherein said transmitting means comprises an RF transmitter.

44. A system according to claim 42,

15 wherein said first remote receiver comprises

an RF receiver for receiving the encoded signals transmitted from each of said monitors and

20 telephone means for transmitting the volumetric flow data for said monitors, and

wherein said second remote receiver comprises telephone receiver means.

25 45. A system according to claim 42, wherein said first remote receiver comprises said means for computing a total volumetric flow for said individual unit and said periodically transmitted volumetric flow data for said individual unit comprises said total volumetric flow.

30 46. A system according to claim 42, wherein said periodically transmitted volumetric flow data comprises the volumetric flow for each of said monitors and said second remote receiver comprises

means for computing a total volumetric flow for an individual unit from said transmitted volumetric flow data.

47. A system for computing the water related energy use of an individual unit of a multi-unit building wherein the multi-unit building is supplied water from a common source and the individual unit has a plurality of energy consuming water devices each supplied by a water pipe supplied from said common source, comprising

monitor means for monitoring the flow through each of said water pipes, each of said monitor means including

means for determining that successive volumetric flow units have flowed through said pipe,

means for defining the heat energy of each of said successive volumetric flow units, and

means for computing a total heat energy for said successive volumetric flow units, and

means for periodically transmitting said total heat energy for said successive volumetric flow units, and

remote receiver means for

receiving said total heat energy transmitted from each of said plurality of monitors for said successive volumetric flow units, and

computing a total heat energy use for said individual unit for a selected period of time.

48. A system for computing the water related energy use of an individual unit of a multi-unit building according to claim 47, further comprising means for computing a heat energy charge for said total heat energy use.

49. A system for computing the water related energy use of an individual unit of a multi-unit building according to claim 48, further comprising means for preparing a bill to the individual unit for said total heat energy charge.

50. A system for computing the water related energy use of an individual unit of a multi-unit building according to claim 49, further comprising means for forwarding said bill to the individual unit for said total heat energy charge.

51. A system for computing the water related energy use of an individual unit of a multi-unit building according to claim 47, wherein said plurality of energy consuming water devices includes at least one hot water consuming device supplied by a hot water pipe, and wherein said monitor means comprises a single monitor.

52. A system for computing the water related energy use of an individual unit of a multi-unit building according to claim 47, wherein said plurality of energy consuming water devices includes at least one heating/cooling device supplied by a water pipe, and wherein said monitor means comprises a monitor on either side of said heating/ cooling device and said remote receiver means computes a total heat energy use for each heating/cooling device by subtracting the total heat energy of one of said monitors from the total heat energy of the other of said monitors.

53. A system for computing the water related energy use of an individual unit of a multi-unit building according to claim 47, wherein said plurality of energy consuming water devices includes at least one heating/cooling device supplied by a water pipe, and

wherein said monitor means comprises a first monitor on one side of said heating/cooling device for determining the temperature of the water and a second monitor for determining the volumetric flow through the pipe and determining the temperature of the water, said second monitor connected to said first monitor and further including means for computing a total energy use of each of said successive volumetric flow units by differencing the temperatures of said first and second monitors.

54. A system for computing the water related energy use of an individual unit of a multi-unit building according to claim 47, wherein said remote receiver means comprises

15 a first remote receiver for receiving the total heat energy from each of said monitors and periodically retransmitting heat energy data for said monitors, and

20 a second remote receiver for receiving the heat energy data from said first remote receiver, said second remote receiver including said means for computing a heat energy charge for said total heat energy use and said means for preparing and forwarding a bill to the individual unit for said total heat energy charge.

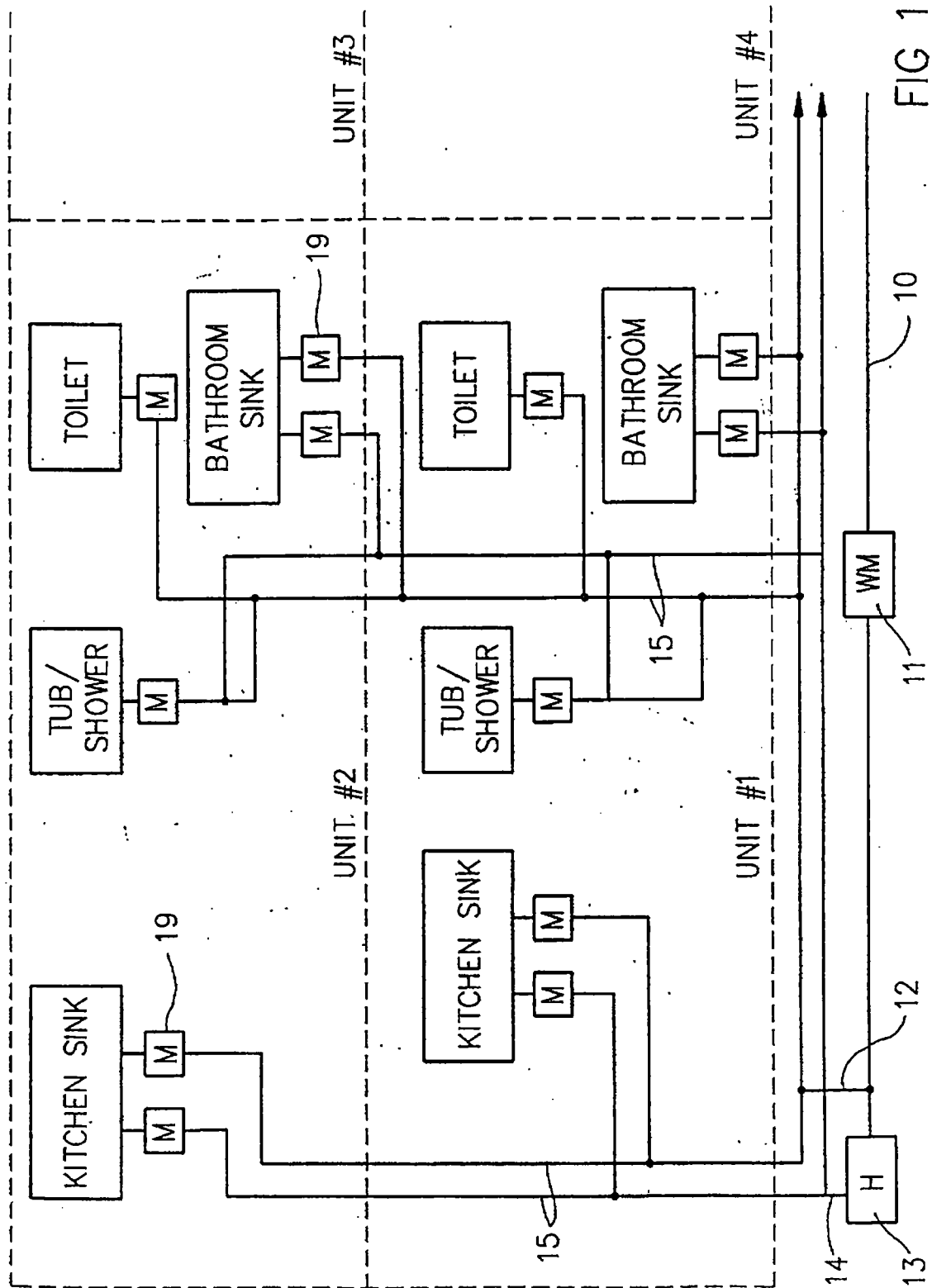
55. A system for computing the water related energy use of an individual unit of a multi-unit building according to claim 54, wherein said first remote receiver comprises means for calculating the total heat energy of the hot water for said individual unit for a selected period of time and said total heat energy for the individual unit comprises the heat energy data transmitted from said first remote receiver to said second remote receiver.

56. A system for computing the water related energy
use of an individual unit of a multi-unit building
according to claim 55, wherein said second remote
receiver comprises means for calculating the total
5 heat energy of the hot water for said individual unit
for a selected period of time and said total heat
energy for each monitor comprises the heat energy
data transmitted from said first remote receiver to
said second remote receiver.

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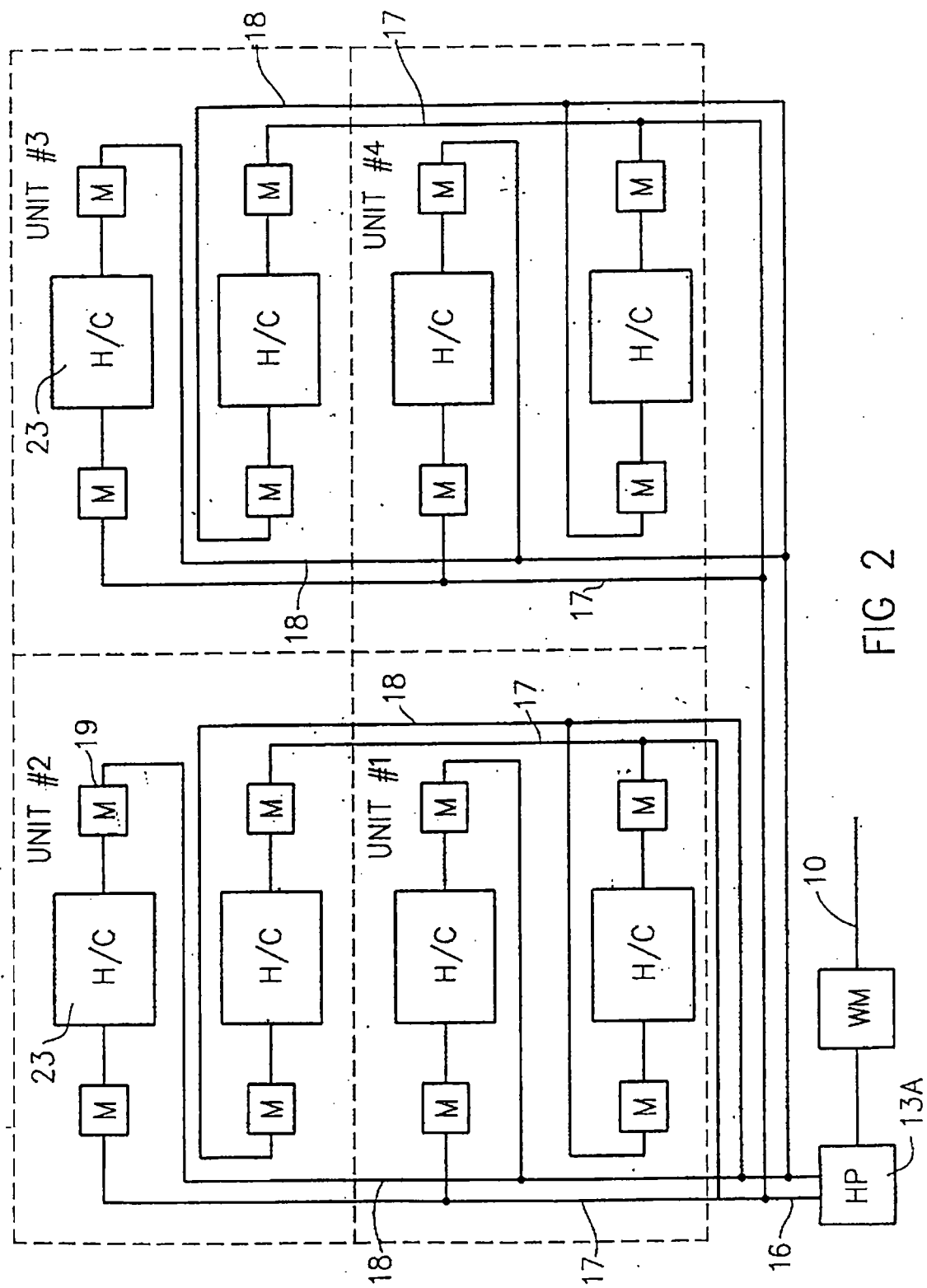


FIG 2

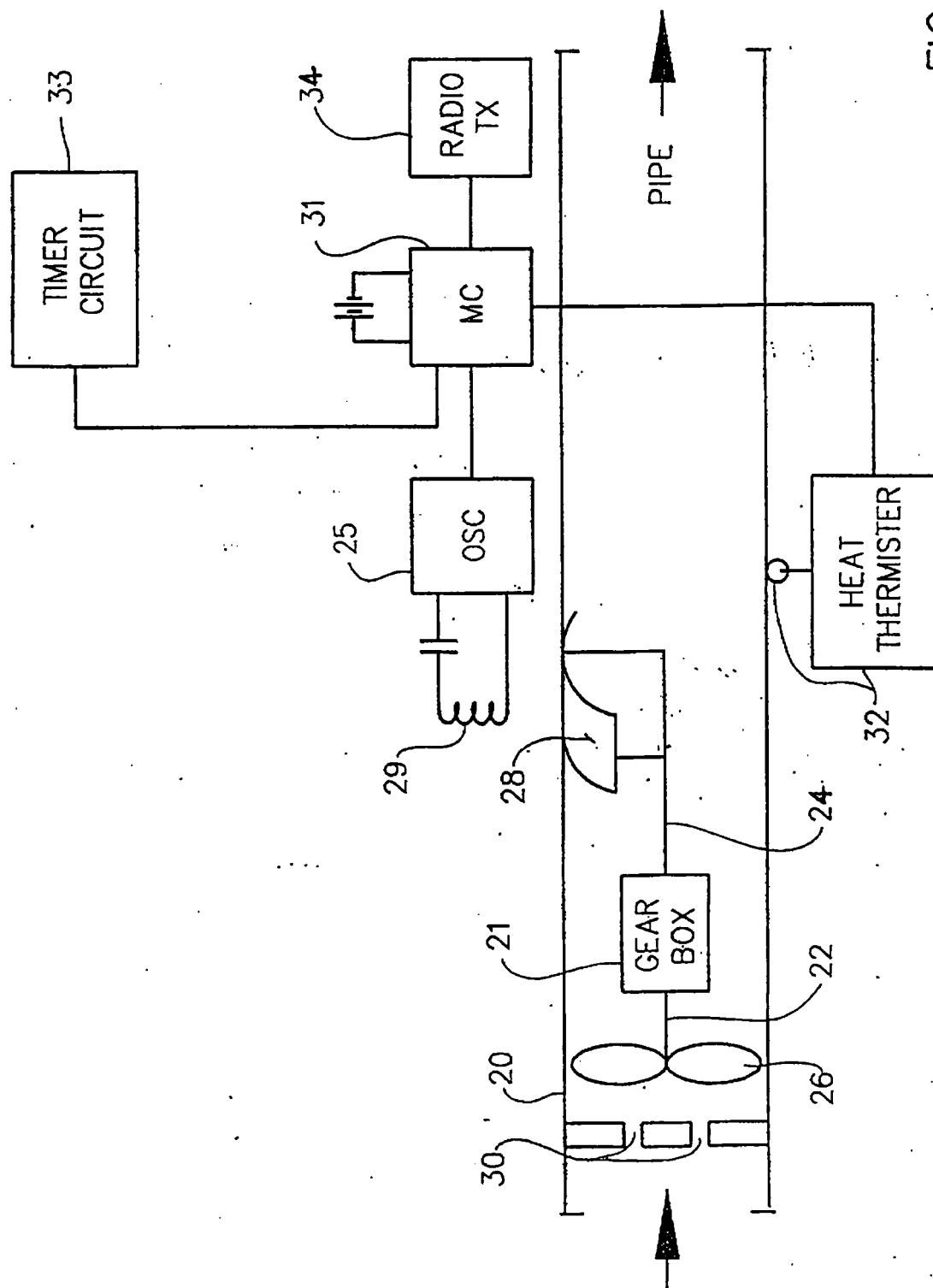


FIG 3

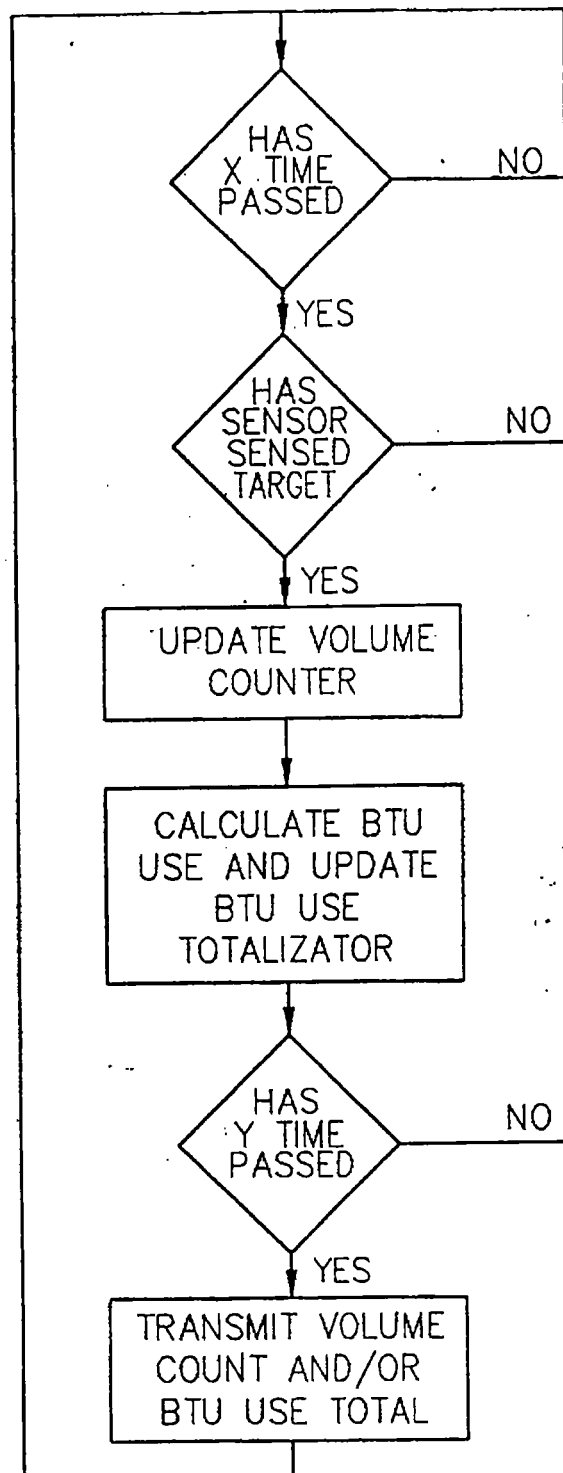


FIG 4

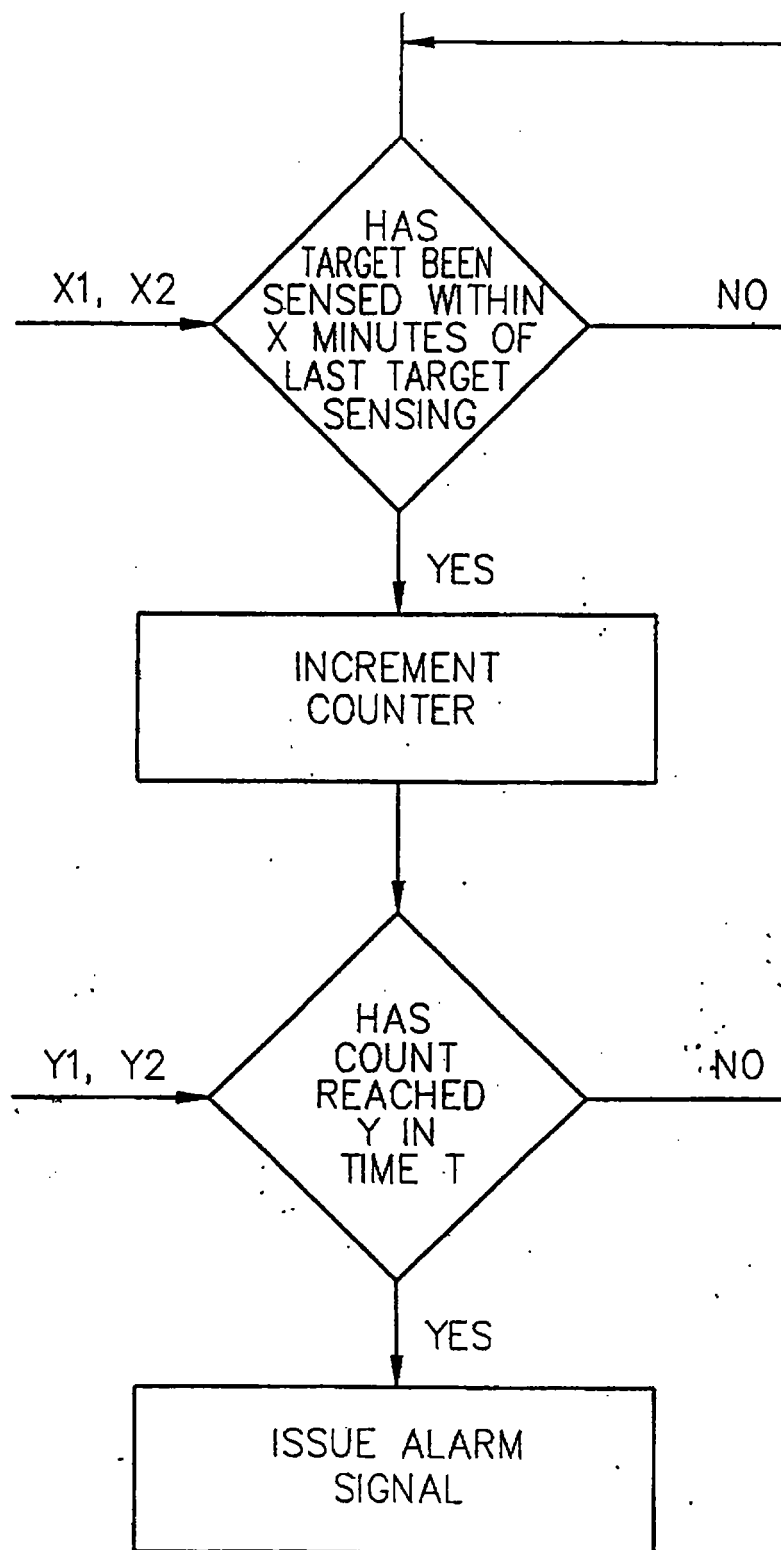


FIG 5

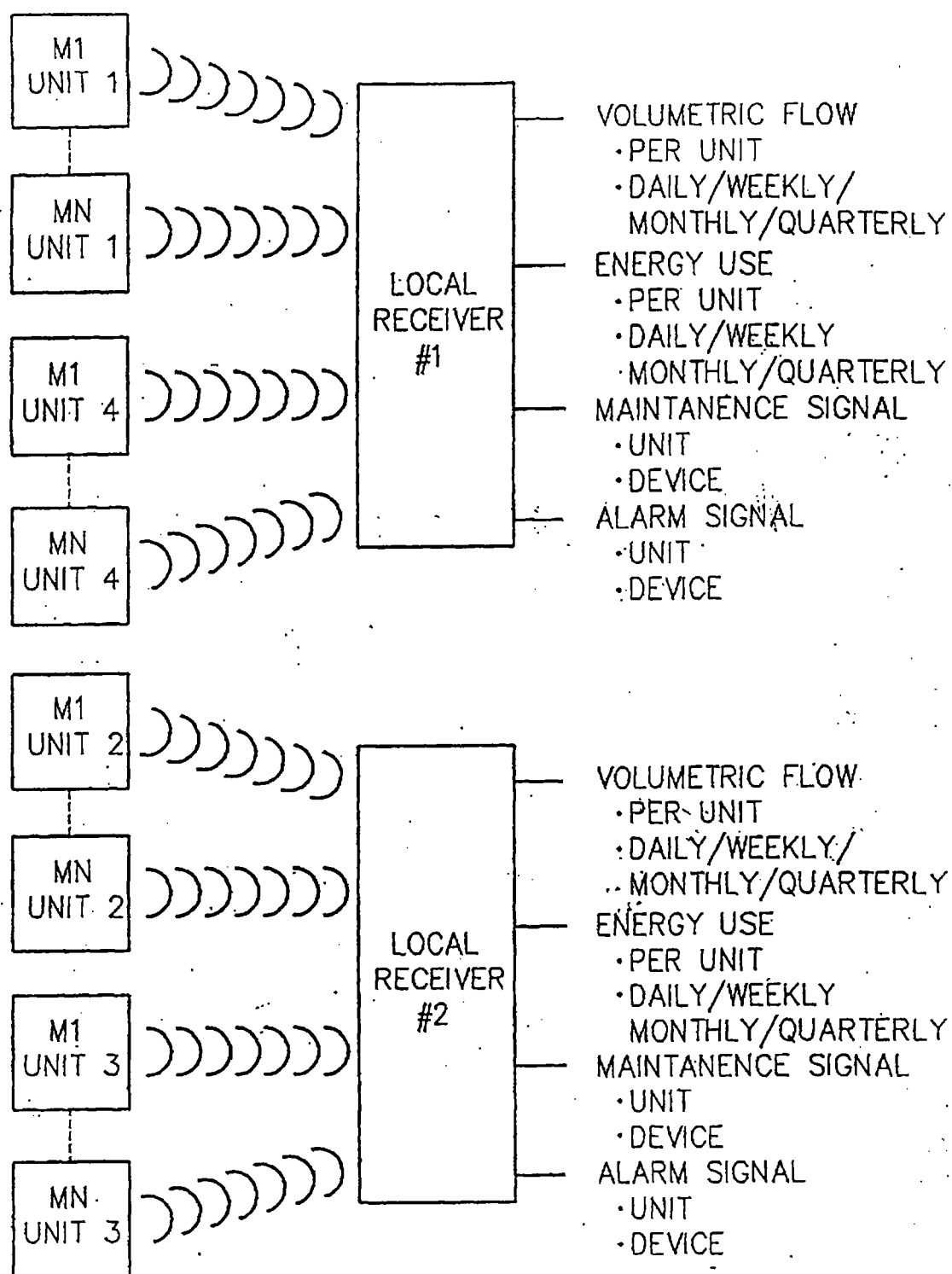


FIG 6

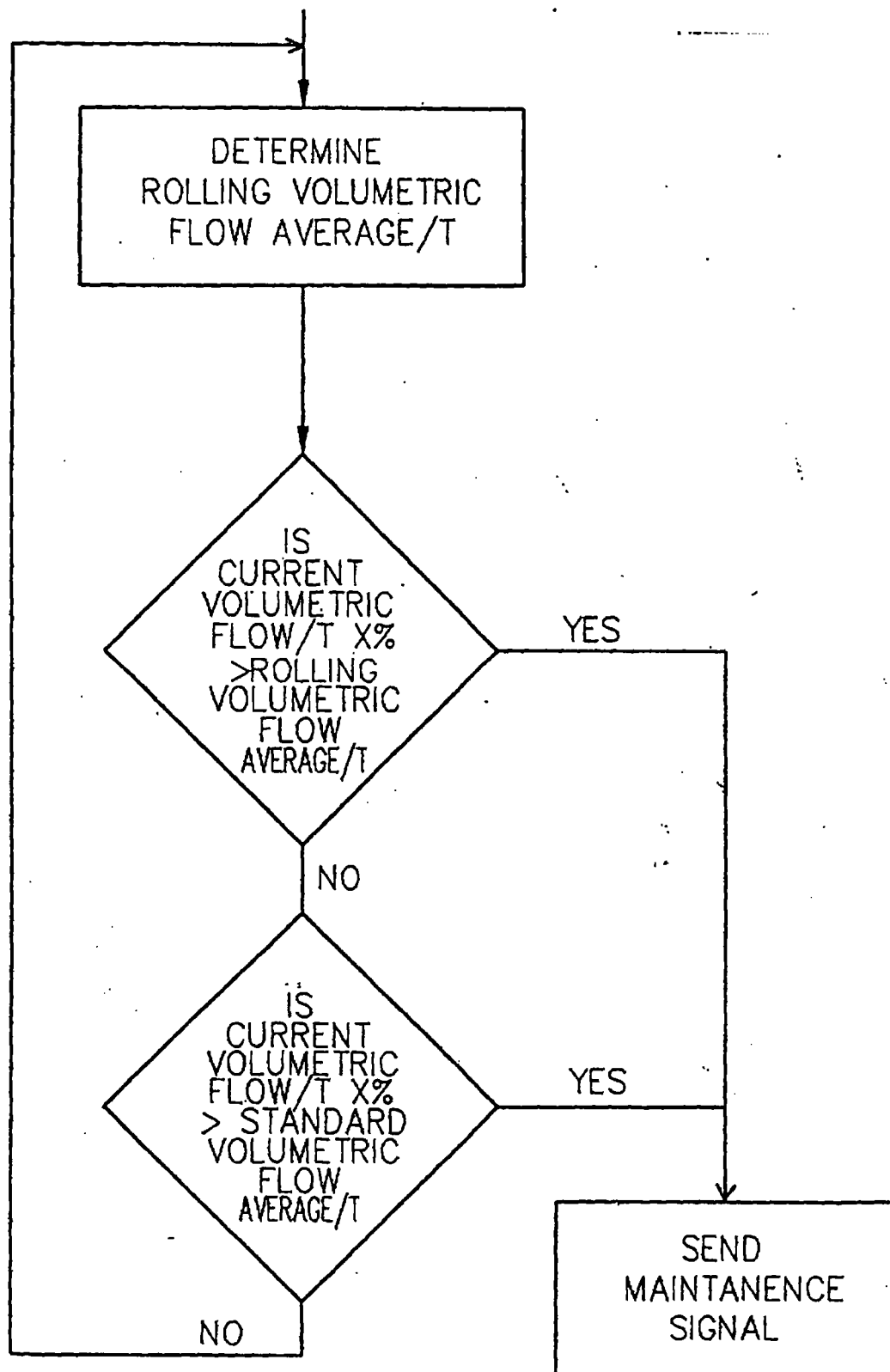
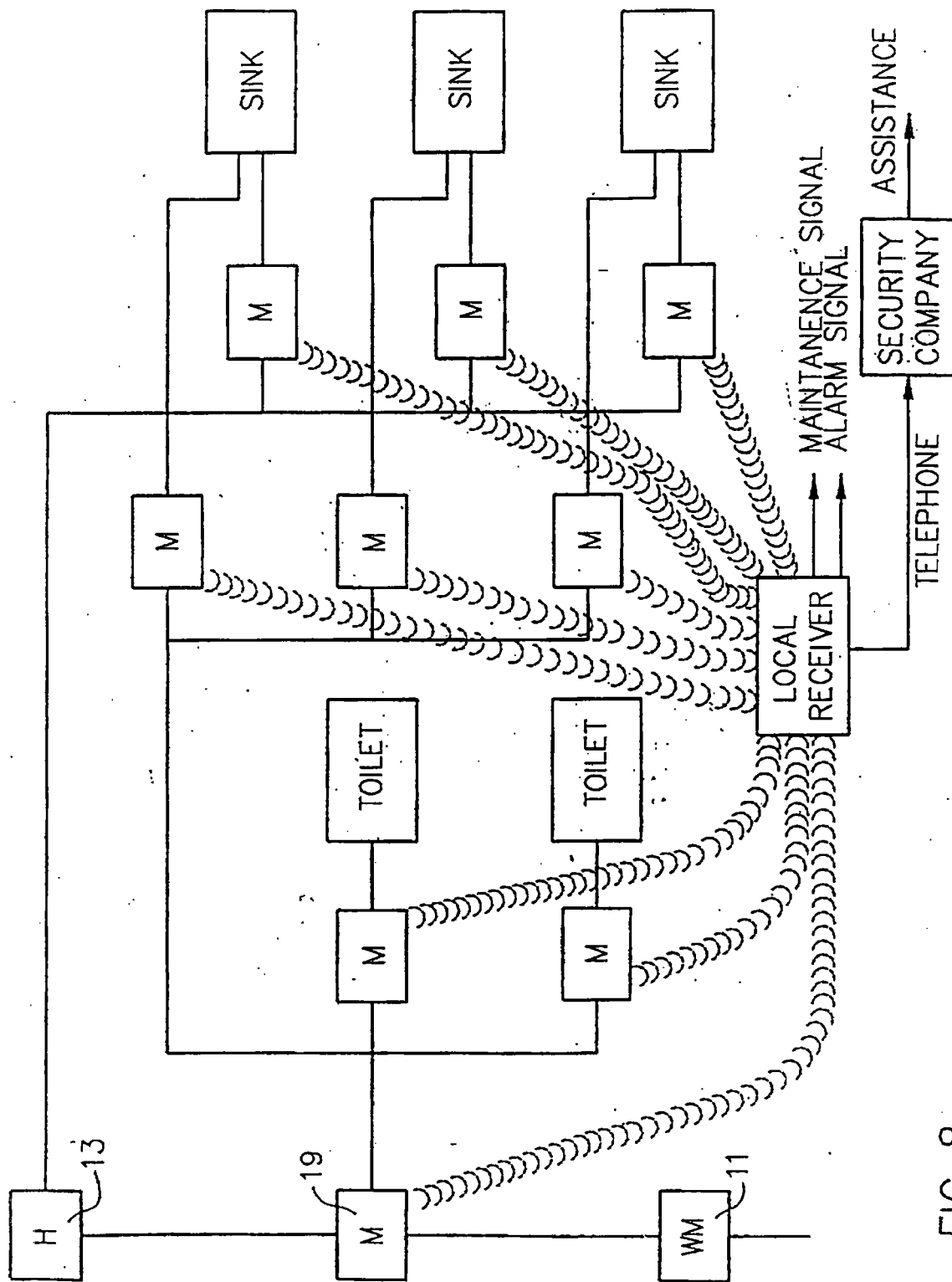


FIG 7



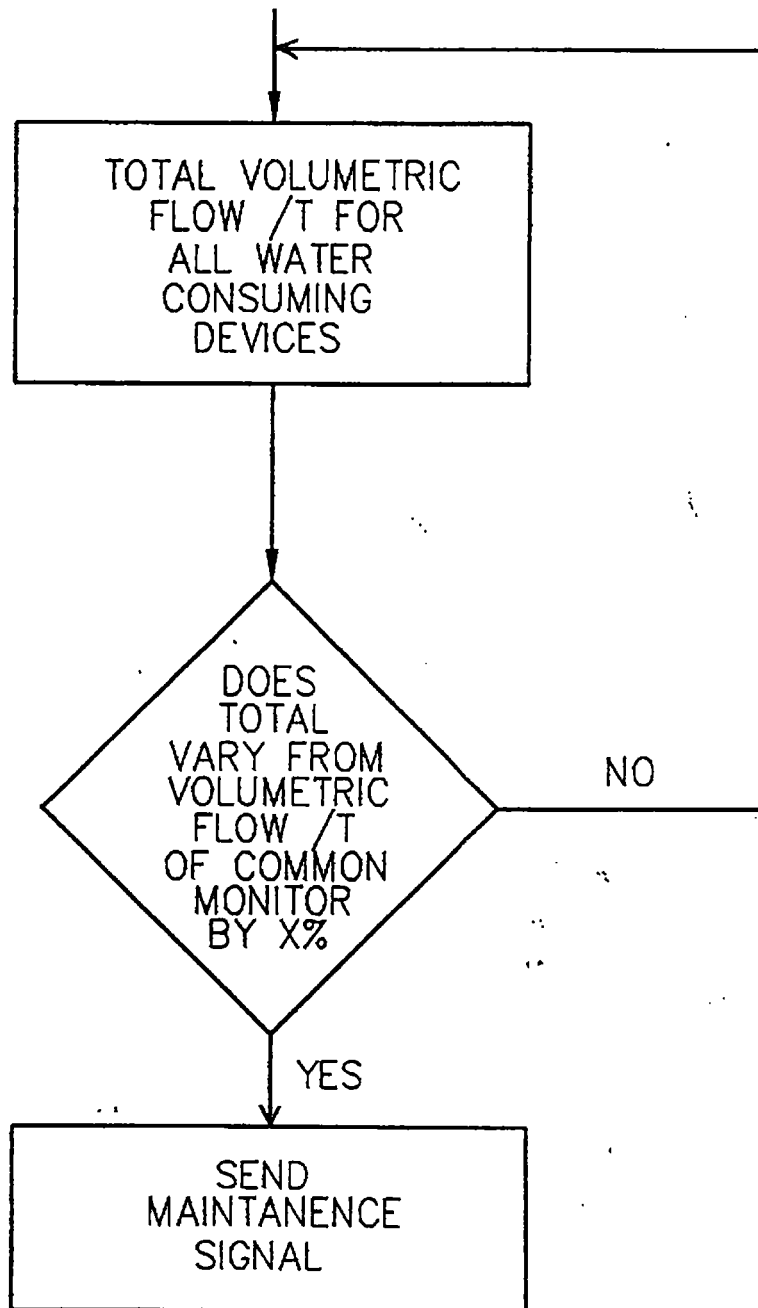


FIG 9

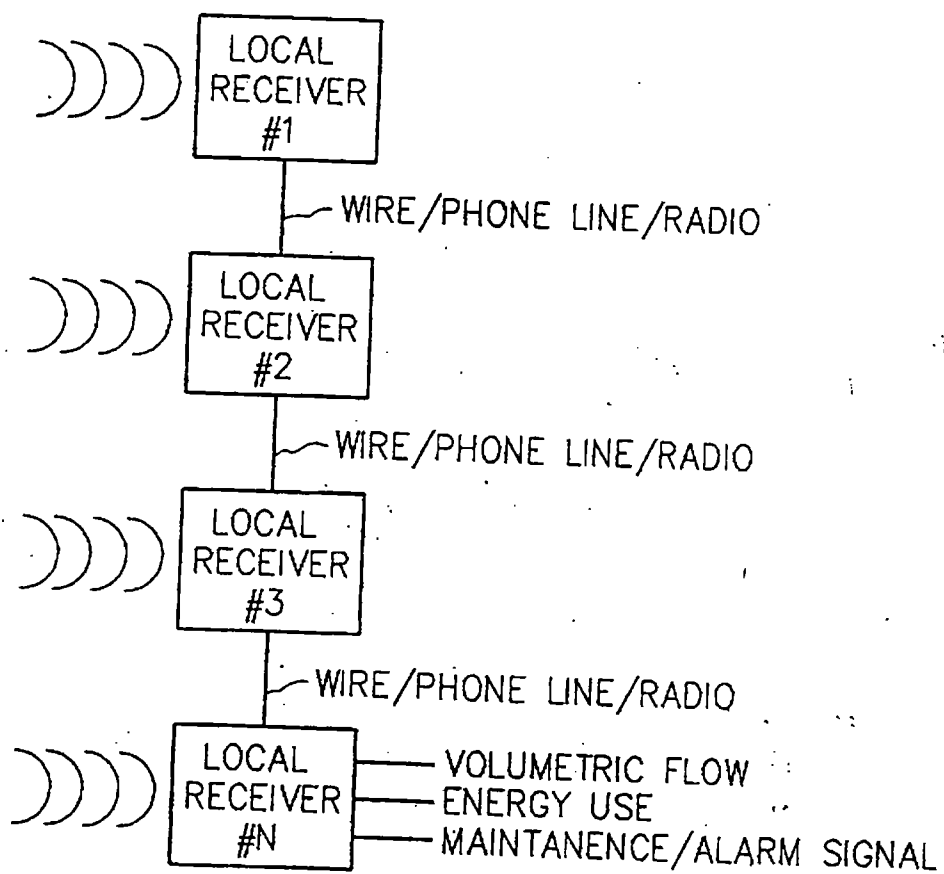


FIG 10

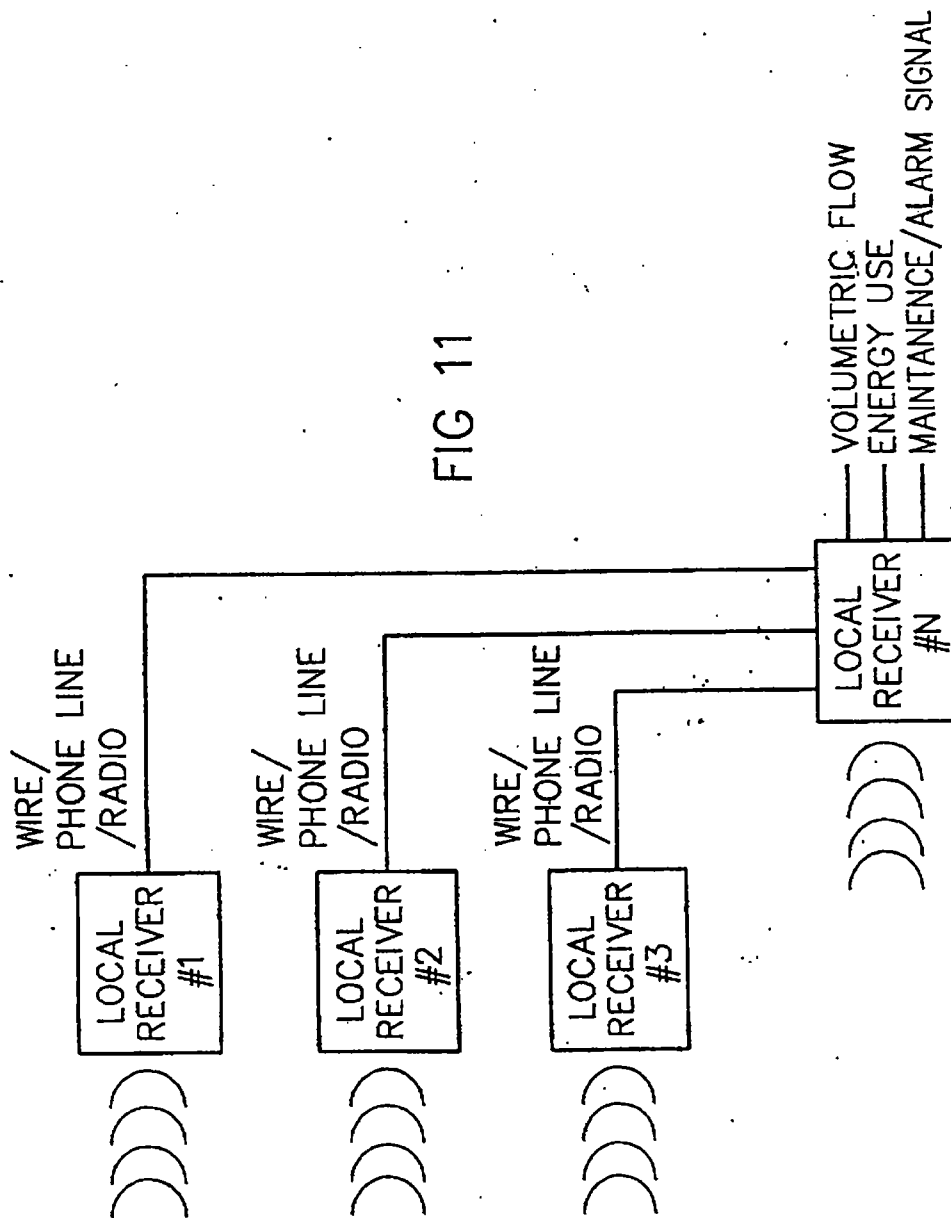


FIG 11

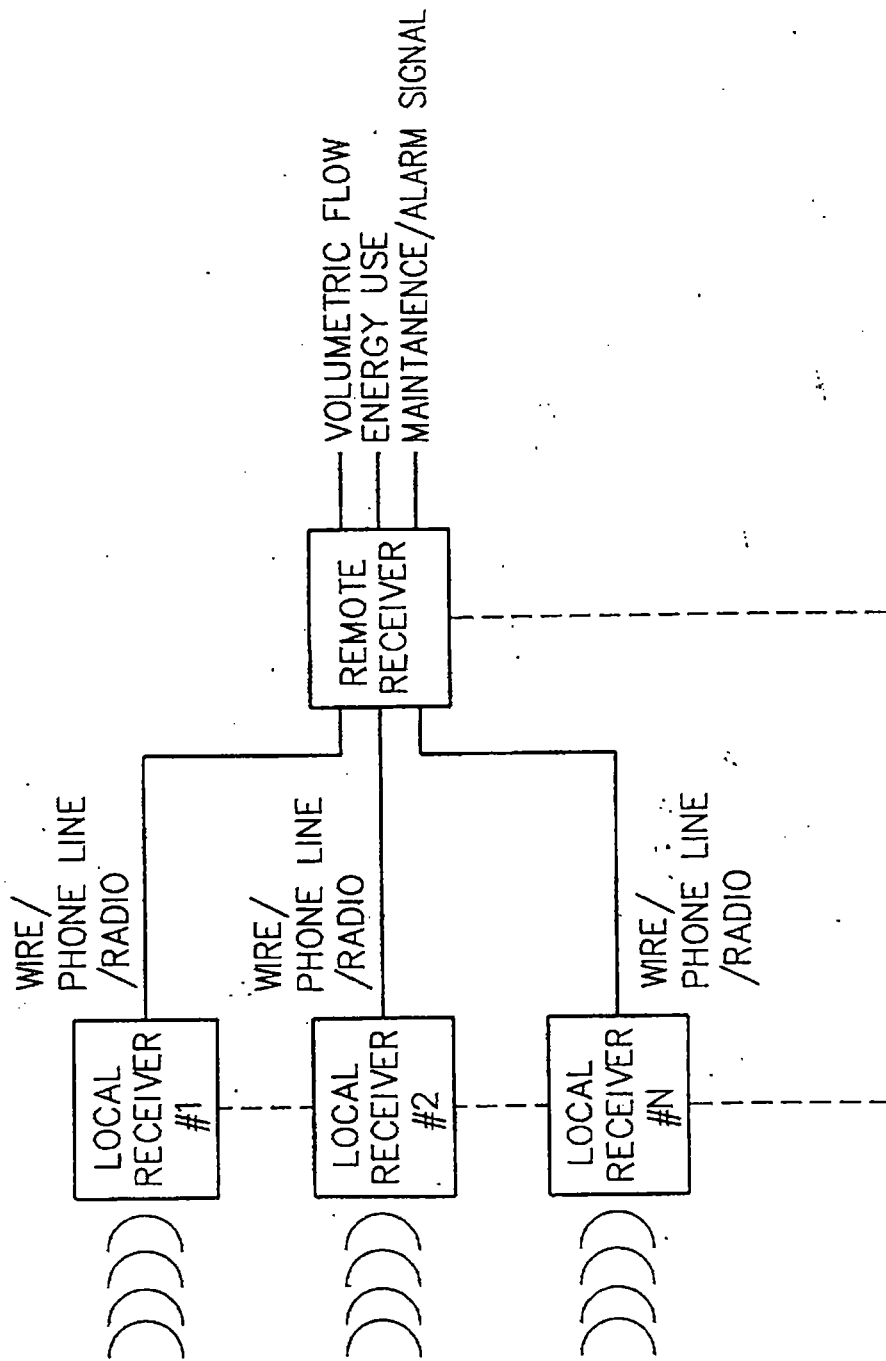


FIG 12

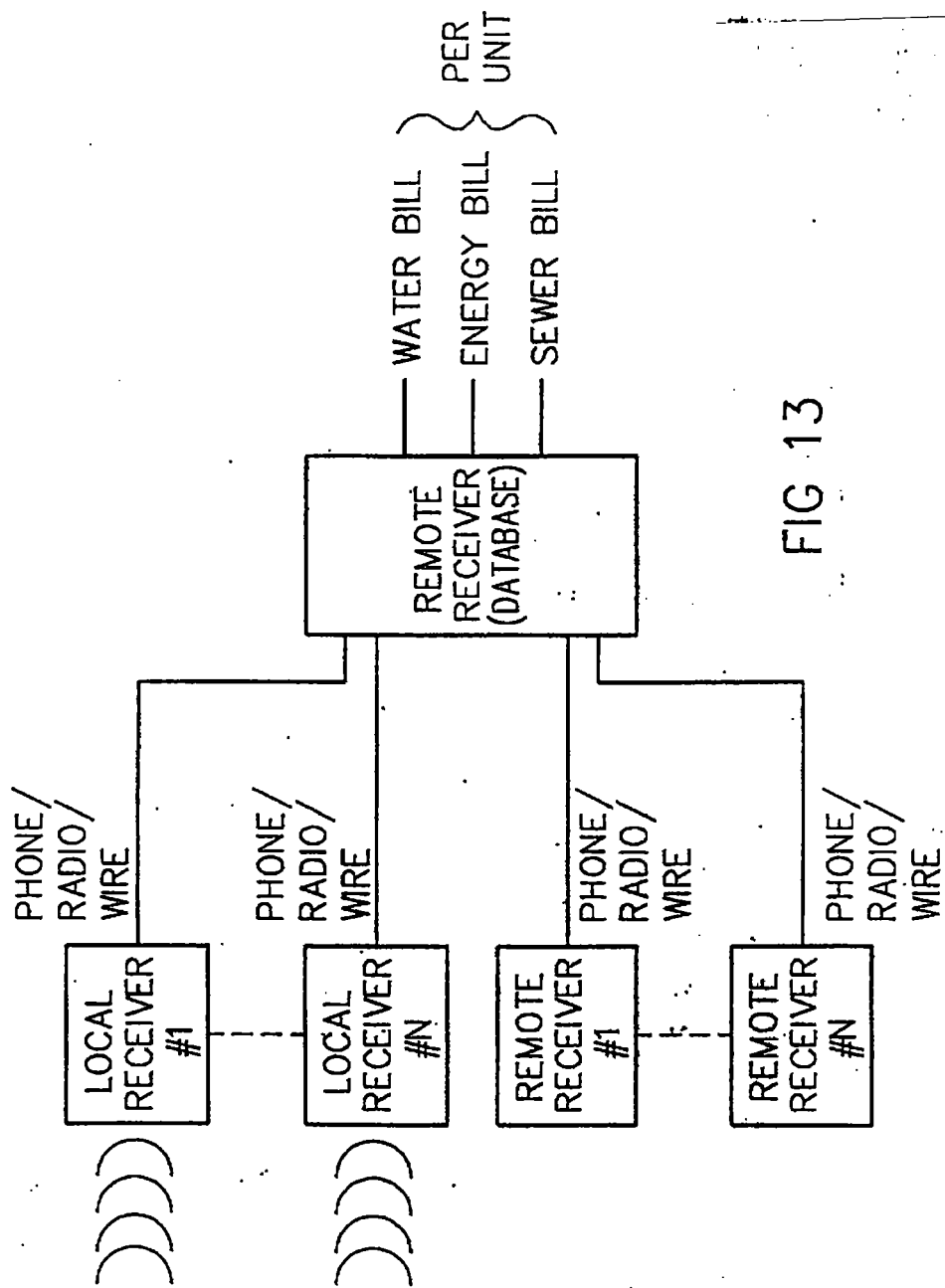


FIG 13

SPECIFICATION

5 SYSTEM FOR MONITORING WATER CONSUMING STRUCTURES AND THEIR HEAT USE IN AN INDIVIDUAL UNIT OF A MULTI- UNIT BUILDING AND A SYSTEM FOR BILLING THEREFOR

BACKGROUND OF THE INVENTION

The present invention relates to a system for monitoring the water consumption and energy use of water consuming devices and monitoring the energy use
10 of water operated heating and cooling devices in multi-unit building complexes where the individual units are supplied water from a common source and more particularly to a system which will calculate the water consumption and water related energy use of
15 the individual units so that water, sewer and energy costs can be fairly apportioned to the units to encourage conservation. The invention also relates to monitoring unusual water usage to detect leaks and open valves.

20 SUMMARY AND OBJECTS OF THE INVENTION

The individual units of a multi-unit building such as an apartment building are supplied water from a common source (the outlet of the building water meter). The water inlet is split into hot and cold
25 water lines with the hot water line passing through a heater (typically there are separate hot water and heating boilers) which heat the water to the required temperature. In conventional construction, multiple vertical risers supply stacked bathrooms, kitchens
30 and heating/cooling devices. As a result the water supplied to an individual unit can not be metered without substantial, very costly, plumbing infrastructure changes.

It is an object of the present invention to
35 measure the water consumption and the water heat

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energy use in an individual unit in a multi-unit building so that the individual unit can be assigned responsibility therefor without substantial plumbing infrastructure changes.

5 It is another object of the present invention to monitor the condition of a water consuming structure so that leaks can be serviced and erroneously open lines can be closed.

BRIEF DESCRIPTION OF THE DRAWINGS

Referring to the drawings:

Figure 1 is a schematic illustration of the water consuming devices of a four unit apartment building wherein each unit has a bathroom with a sink (including any associated tub/shower) and a toilet and a kitchen with a sink (including associated appliances such as a dishwasher) and wherein each pipe supplying the water consuming devices includes a monitor made in accordance with the teachings of the present invention;

Figure 2 is a schematic illustration of the heating/cooling system for the same apartment building wherein each apartment has one or more heating/cooling devices each having upstream and downstream monitors, one monitoring temperature and volumetric flow and the other monitoring temperature;

Figure 3 is a schematic illustration of a monitor shown in figures 1-2;

Figure 4 is a logic diagram for the volume/temperature functions of a monitor;

Figure 5 is a logic diagram for a monitor which will issue an alarm signal when the water using device is continuously open;

Figure 6 is a schematic illustration of a system for a multi story building including a receiver on each floor for receiving and outputting data from the

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monitors on its floor;

Figure 7 is a logic diagram for a monitor which will issue a maintenance signal when a water device is leaking;

5 Figure 8 is a schematic illustration for a home system;

Figure 9 is a logic diagram for comparing the output of a common monitor with the outputs of all the dedicated monitors to identify a leak;

10 Figure 10 is a schematic illustration of a system for a building that has a plurality of local receivers that are hard wired in series with the base local receiver outputting data;

15 Figure 11 is a schematic illustration of a system similar to that of figure 6, with individual local receivers hard wired or phone linked in parallel to a base local computer;

20 Figure 12 is a schematic illustration of a system having a plurality of local receivers linked in series or in parallel to a remote receiver; and

Figure 13 is a schematic illustration of a system having a plurality of local and remote receivers which are linked to a data base.

DESCRIPTION OF THE PREFERRED EMBODIMENT

25 Utility provided water 10 (fig. 1) generally is metered by a water meter WM 11 as it enters a building such as an apartment house or office building. A portion of the water branches off to supply the building cold water supply line 12 and the
30 other portion is supplied to a hot water heater H 13 which supplies the hot water supply line 14 of the building. The building has a number of similar units (in a two story apartment house, there could be four one bedroom apartments, two on each floor, for
35 example) each having a sink (including associated tub/shower) and toilet in the powder room and a

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second sink (including any associated appliances such as a dishwasher) in the kitchen. Each sink is supplied by separate hot and cold water lines (the hot and cold water lines of the kitchen sink may also supply a dishwasher) and each toilet is supplied by a single cold water line. Stacked kitchens and bathrooms are supplied via vertical risers 15. In each water line (or just downstream in the mixed water line) is located a monitor M 19. Figure 2 shows the heating/cooling system for the same units. Water (hot in the winter or cold in the summer) is supplied by a suitable source such as a heat pump HP 13A (discrete sources such as a boiler for hot water and a chiller for cold water could be utilized) to a feed line 16 which supplies the individual heating or cooling units H/C 23 through multiple vertical risers 17. The water is returned to the source HP by suitable return lines 18. Located upstream and downstream of each heating or cooling unit H/C is a monitor M.

A monitor M (fig. 3) which can be located in each line by a plumber, is a unitary battery operated structure, which is fully sealed to reduce tampering and water damage. The monitor can have a universal set of fittings to simplify installation. A monitor may include a pipe 20 in which may be permanently secured a gearbox 21 such as the type found in lawn sprinkler heads to control the movement of the water spray. The gear box has axial input 22 and output 24 shafts which are connected to a turbine wheel drive propeller 26 and a copper or other metal axially extending partial cylindrical portion paddle wheel 28. Water entering the pipe, passes through a set of orifices 30 which direct the water at the propeller blades thereby efficiently driving the gearbox. The gear ratio of the gearbox is selected so that the partial cylindrical portion 28 will make no more than

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about half a rotation during a sampling time (a rate of rotation that will assure that an oscillator (OSC - 25) will sense the presence of the partial cylindrical portion (the target) 28 twice each revolution). The gear ratio may be different for different devices (full flow for a toilet is very different than full flow for a tub, for example). Coil 29 will change inductance twice each revolution changing the frequency of the oscillator. The microprocessor uc 31 or custom specialized electronic circuit can therefore count a pulse each time the target 28 is located at 0° and 180° and each pulse equates to a unit volume of liquid. Referring to figure 4, if a reading is to be taken approximately once per "X" time (a minute, for example) based on a timer circuit 33 associated with the microprocessor (see figure 3), the gear ratio will be selected so that the target will rotate less than 180°, during one minute with maximum flow through the pipe. Alternately, other sensors could be used such as a rotating magnet and Hall effect sensor, reed switch, capacitive sensor, optical sensor, inductive sensor with ferrite rotator, etc. When, during that time interval, the target has been sensed, a volume counter will be updated to a new total of volume units and at some other regular time interval "y" (once a day, for example), the total volume count will be transmitted by the radio transmitter 34. The updated count is representative of the total volumetric flow through the pipe. Limiting the rate of rotation of the target with the gear box so that a reading need only be taken once per minute, prolongs battery life since the microprocessor uc only has to be turned on once per minute. The flow measuring system could also be an ultrasonic Doppler flowmeter, a magnetic flowmeter, an electronic mass flowmeter, or a vortex flowmeter, for example.

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The energy use of the hot water used in a water using device may be computed by multiplying the volumetric volume of the associated hot water pipe by the temperature that hot water is supplied where the monitor is receiving hot water from the hot water heater. Optionally, the monitor can include a heat thermistor 32 (or a thermocouple, etc.) attached to the pipe to sense the temperature of the fluid flowing through the monitor. The microprocessor uc 31 may multiply the temperature by that unit volumetric flow to define a heat content number (BTU use - figure 4) and will then update the total heat content totalizator. By subtracting the total heat count at one side of a heating/cooling unit H/C from the simultaneous total heat count at the other side (the subtraction made by a local receiver which receives the data from both monitors - Figure 7, for example), the energy use of the heating/cooling unit can be determined. Alternately, one of the monitors on either side of a heating/ cooling unit can monitor only temperature and be connected to the other monitor with that monitor making both computations such as by subtracting out the temperature reading from the other to compute the heat change. Should electrical power be available or should the battery economics permit, the position of the target could be sampled continuously and the gear box would not be required.

Once every day (or some other time interval) which equates to "Y" time interval, the microprocessor will operate the transmitter (which is a radio transmitter 33 in the preferred embodiment but could be an ultra sonic or infrared transmitter, etc.) to transmit the then current count of the register which is representative of volumetric flow, the then current total of the heat content totalizator, identifier data which identifies the apartment

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unit, the water using device, etc. and any pulse count data used to chronologically locate the transmission.

5 The microprocessor uc can also determine that a water consuming device has been left open (a tub running continuously, for example). For example, the microprocessor should detect the presence of the target once a minute while the tub is being filled at the fully open condition. Even at a slow fill rate
10 the target should be sensed once every "X" minutes (figure 5). If "X" is five minutes, for example, the filling process should be complete within twenty minutes (four multiples of "X"). Accordingly, according to the algorithm expressed in figure 5,
15 when the water has been running for "X" minutes and the target has been sensed, the counter is incremented and the process is repeated. When the target has been sensed in the next "X" minutes the counter again increments and so forth. If the count
20 reaches 15 ("Y"), for example, the water has run for a time beyond that which was required to fill the tub and this can mean that someone has failed to turn the water off, etc. Should the microprocessor determine that flow has continued for more "Y" increments of
25 "X", the microprocessor will direct the transmitter to transmit an alarm signal, identifying the water consuming device, to the receiver which indicates that the device has been left open so that immediate action can be taken to correct the problem. The
30 alarm signal can be transmitted to a local receiver which could be a general alarm system for the home which would announce the condition or it could be further transmitted to a remote receiver which could be at a home security company which could take
35 appropriate action or it could be a part of the water usage system for a multiple unit building as described herein. This algorithm can also be

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computed with a number of "X" and "Y" values ("X1" and "Y1", "X2" and "Y2", for example) since the fill rate can be chosen at widely different rates. These variables can also be defined during installation by programming non volatile memory in the monitor.

In the apartment illustrated in figures 1 and 2, a radio (local) receiver (a microprocessor, for example) which can receive and decode the transmitted radio signal can be located on each floor (figure 6) for receiving the data transmitted from all of the monitors on its floor. As shown in figure 6, the local receiver may compute daily, weekly, monthly, quarterly, etc., totals for the volumetric flow and energy (BTU) use for each unit, and can issue alarm signals (by audible alarm or telephone to a security location, for example, identifying the unit and the water consuming device subject to the alarm signal. Each receiver could, for example, have a visual readout or it could be connectable to a hand held terminal which can read out the data. By transmitting volumetric flow data from the monitors to the receiver each day, the receiver can determine that a monitor is not operating which could indicate that the monitor battery has died, etc., or that the monitor has been tampered with.

The local receiver may also implement the algorithm disclosed in figure 7. It can determine a rolling volumetric flow average/unit of time ("T" may be 30 or 60 days for example) and first compare that with the calculated current volumetric flow/unit of time. Where it exceeds the rolling average by X% which indicates the a faucet is leaking, for example, the local receiver will send a maintenance signal. A second comparison can also be made to determine whether the current volumetric flow/unit of time exceeds by Y% a standard for that device. Should the difference exceed this variance, the local receiver

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will issue a maintenance signal.

The receiver, in its simplest form, could contain an information system (or a part of a larger information system) for an individual unit or a home, (figure 8). A monitor which would not have to monitor temperature, could be placed in each line supplying the water consuming devices so that volumetric flow data could be transmitted to a local receiver which would determine whether any device was leaking or open and would issue an appropriate alarm or maintenance signal for that device. This figure also illustrates a monitor downstream of the water meter WM - 11. This monitor can implement the algorithm of figure 5 to detect a break in any downstream water line such as could happen as a result of earthquake or freeze damage, for example. By comparing the volumetric flow/unit of time of this common monitor (figure 9), with the total/unit of time of all the dedicated monitors, an internal leak can be identified (a variance of X% would indicate an internal leak). Maintenance and alarm signals can be issued by the local receiver and optionally the local receiver can communicate with a remote receiver in the form of a security company or to the monitoring or billing system to obtain assistance..

As shown in figure 10, the multi-unit building may have a plurality of local receivers hard wired in series (or connected on a phone line) to a base local receiver (the local receiver located on the superintendents' floor for example), with the base local receiver presenting the data for all the local receivers. Instead of phone lines or wires, a radio (custom or PCS system) could transmit the data from one local receiver to other local/remote receivers. The total volumetric flow and energy use for an individual unit can be computed by each of the local receivers or all computations can be performed by the

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base local receiver. Alternately, such a base local receiver can be connected in parallel with the other local receivers (figure 11). The base receiver may not receive data from a monitor but only receive data
5 from local receivers (receivers receiving data from monitors (figure 12). The base receiver is then a remote receiver. The remote receiver (figure 13) can provide a database which communicates via phone lines with any number of local and/or remote receivers and
10 a receiver (a local receiver, a base local receiver or a remote receiver) can operate on the data and prepare, bills for water, energy and sewer use for each reporting unit which can be sent directly to the individual units or to the buildings for distribution
15 as well as support reporting of leaks and open faucets, etc.

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Claims:-

1. A system for monitoring the use of heat energy in a plurality of energy consuming water devices in an individual unit of a multi-unit building wherein each energy consuming water device is supplied by a water pipe comprising

at least one monitor for monitoring the flow through each of the plurality of water pipes, each of said monitors including

meter means for determining that successive volumetric flow units have flowed through the pipe,

temperature sensing means for sensing the temperature of the water flowing through the water pipe,

multiplying means for defining the heat energy of each of said successive volumetric flow units by multiplying the temperature times the increment of flow,

totalizator means for computing a total heat energy for said successive volumetric flow units, and

a transmitter for periodically transmitting said total heat energy for said successive volumetric flow units, and

a first remote receiver for receiving the total heat energy transmitted by the transmitter of each of said plurality of monitors and periodically retransmitting the total heat energy received from each of the monitors, and

a second remote receiver for receiving the total heat energy for each of said monitors retransmitted from said first remote receiver and for periodically computing the total heat energy of the water for said plurality of monitors.

2. A system for monitoring the use of heat energy in energy consuming water devices in an individual unit of a multi-unit building according to claim 1, wherein said plurality of energy consuming water devices includes at least one hot water consuming device which discharges hot water during use and wherein a single monitor monitors the flow through each of the hot water consuming devices that discharge hot water during use.

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3. A system for monitoring the use of heat energy in energy consuming water devices in an individual unit of a multi-unit building according to claim 1, wherein said plurality of energy consuming water devices includes at least one heating/cooling device supplied by a water pipe, and wherein first and second monitors are located on either side of each of said heating/cooling devices and said second remote receiver computes a total heat energy use for each of the heating/cooling devices by subtracting the total heat energy of the first monitor monitoring the flow through the heating/cooling device from the total heat energy of the second monitor monitoring the flow through the heating/cooling device.

4. A system for monitoring the use of heat energy in energy consuming water devices in an individual unit of a multi-unit building according to claim 3, wherein said plurality of energy consuming water devices includes at least one hot water consuming device which discharges hot water during use and wherein a single monitor monitors the flow through each of the hot water consuming devices that discharge hot water during use.

5. A system for monitoring the use of heat energy in a plurality of heat energy using water devices in an individual unit of a multi-unit building wherein each water device discharges hot water supplied by a water pipe comprising

a monitor for monitoring the flow through each of the plurality of water pipes, each of said monitors including

meter means for determining that successive volumetric flow units have flowed through the pipe,

temperature sensing means for sensing the temperature of the water flowing through the water pipe,

multiplying means for defining the heat energy of each of said successive volumetric flow units by multiplying the temperature times the increment of flow,

totalizator means for computing a total heat

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energy for said successive volumetric flow units, and

a transmitter for periodically transmitting said total heat energy for said successive volumetric flow units, and a first remote receiver for receiving the total heat energy transmitted by the transmitter of each of said plurality of monitors and periodically retransmitting the total heat energy received from each of the monitors, and

a second remote receiver for receiving the total heat energy for each of said monitors retransmitted from said first remote receiver and for periodically computing the total heat energy of the water for said plurality of monitors.

6. A system for monitoring the use of heat energy in a plurality of energy using water devices in an individual unit of a multi-unit building wherein each energy using water device is supplied by a water pipe comprising

first and second monitors located on either side of each of said heating/cooling devices, each of said monitors including

meter means for determining that successive volumetric flow units have flowed through the pipe,

temperature sensing means for sensing the temperature of the water flowing through the water pipe,

multiplying means for defining the heat energy of each of said successive volumetric flow units by multiplying the temperature times the increment of flow,

totalizator means for computing a total heat energy for said successive volumetric flow units, and

a transmitter for periodically transmitting said total heat energy for said successive volumetric flow units, and

a first remote receiver for receiving the total heat energy transmitted by the transmitter of each of said plurality of monitors and periodically retransmitting the total heat energy received from each of the monitors, and

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a second remote receiver for receiving the total heat energy for each of said monitors retransmitted from said first remote receiver and for periodically computing the total heat energy of the water for said plurality of monitors by subtracting the total heat energy of the first monitor monitoring the flow through the heating/cooling device from the total heat energy of the second monitor monitoring the flow through the heating/cooling device.

7. A system for monitoring the use of heat energy in an energy consuming water device in an individual unit of a multi-unit building which is supplied by a water pipe comprising

a monitor for monitoring the flow through the water pipe including

meter means for determining that successive volumetric flow units have flowed through the pipe,

temperature sensing means for sensing the temperature of the water flowing through the water pipe,

multiplying means for defining the heat energy of each of said successive volumetric flow units by multiplying the temperature times the increment of flow,

totalizator means for computing a total heat energy for said successive volumetric flow units, and

a transmitter for periodically transmitting said total heat energy for said successive volumetric flow units,

a first remote receiver for receiving the total heat energy transmitted by said transmitter and periodically retransmitting the total heat energy received from said monitor, and

a second remote receiver for receiving the total heat energy for said monitor retransmitted from said first remote receiver and for periodically computing the total heat energy of the water for said monitor.



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8. A system for monitoring the use of heat energy in an energy consuming water device in an individual unit of a multi-unit building according to claim 7, wherein said energy consuming water device is a hot water consuming device which discharges hot water during use.

9. A system for monitoring the use of heat energy in an energy consuming water device in an individual unit of a multi-unit building according to claim 7, wherein said energy consuming water device is a heating/cooling device.

10. A system for monitoring the use of heat energy in a heating/cooling device in an individual unit of a multi-unit building which is supplied by a water pipe comprising
a monitor for monitoring the flow through the water pipe including

meter means for determining that successive volumetric flow units have flowed through the pipe,

temperature sensing means for sensing the temperature of the water flowing through the water pipe at first and second spaced locations, on either side of the heating/cooling device

multiplying means

for defining the heat energy of each of said successive volumetric flow units at the first location by multiplying the temperature sensed at the first location times the increment of flow and

for defining the heat energy of each of said successive volumetric flow units at the second location by multiplying the temperature sensed at the second location times the increment of flow,

totalizator means

for computing a first total heat energy for said successive volumetric flow units at said first location and

for computing a second total heat energy

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for said successive volumetric flow units at said second location, and a transmitter for periodically transmitting the first and second total heat energy for said successive volumetric flow units, and

a first remote receiver for receiving the first and second total heat energy transmitted by said transmitter and periodically retransmitting the first and second total heat energy received from said monitor, and

a second remote receiver for receiving the first and second total heat energy for said monitor retransmitted from said first remote receiver and for periodically computing the total heat energy of the water consumed by the device.

11. A system for computing a charge for the water related energy use of an individual unit of a multi-unit building wherein the individual unit has a plurality of energy consuming hot water devices which discharge hot water during use, each supplied by a hot water pipe, comprising

a monitor associated with each of the hot water pipes including

means for determining when volume units of hot water have flowed through the hot water pipe as hot water is discharged from the hot water device,

means for sensing the temperature of the hot water,

means for defining the heat energy of each volume unit of hot water flow by multiplying the volume unit of flow by the sensed temperature,

a total heat energy totalizer having a current heat energy total that can be read,

means for updating said total heat energy totalizer with the heat energy defined for each determined volume unit of flow of hot water, and

a transmitter for periodically transmitting the current total heat energy reading of said total heat energy totalizer, and

means for receiving each transmitted current total heat energy reading of each of said totalizers and periodically computing a heat energy charge for the individual unit.

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12. A system for computing a charge for the water related energy use of an individual unit of a multi-unit building according to claim 11, wherein said means for receiving each transmitted current total heat energy reading of each of said totalizers and periodically computing a heat energy charge for the individual unit comprises

a remote receiver for periodically receiving the current total heat energy reading of each of said total heat energy totalizers and periodically transmitting total heat energy information, and

a host computer for receiving the total heat energy information from said remote receiver and computing a heat energy charge for the individual unit.

13. A system for computing a charge for the water related energy use of a device which consumes hot water during use in an individual unit of a multi-unit building wherein the device is supplied by a hot water pipe, comprising

a monitor associated with the hot water pipe including means for determining when volume units of hot water have flowed through the hot water pipe as hot water is discharged from the hot water device,

means for sensing the temperature of the hot water,

means for defining the heat energy of each volume unit of hot water flow by multiplying the volume unit of flow by the sensed temperature,

a total heat energy totalizer having a current heat energy total that can be read,

means for updating said total heat energy totalizer with the heat energy defined for each determined volume unit of flow of hot water, and

a transmitter for periodically transmitting the current total heat energy reading of said total heat energy totalizer, and

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means for receiving each transmitted current total heat energy reading of said totalizator and periodically computing a heat energy charge including the water related energy use of the device represented by a received current total heat energy reading.

14. A system for computing a charge for the water related energy use of an individual unit of a multi-unit building according to claim 13, wherein said means for receiving each transmitted current total heat energy reading of said totalizator and periodically computing a heat energy charge for the individual unit comprises

a remote receiver for periodically receiving the current total heat energy reading of said total heat energy totalizator and periodically transmitting total heat energy information, and

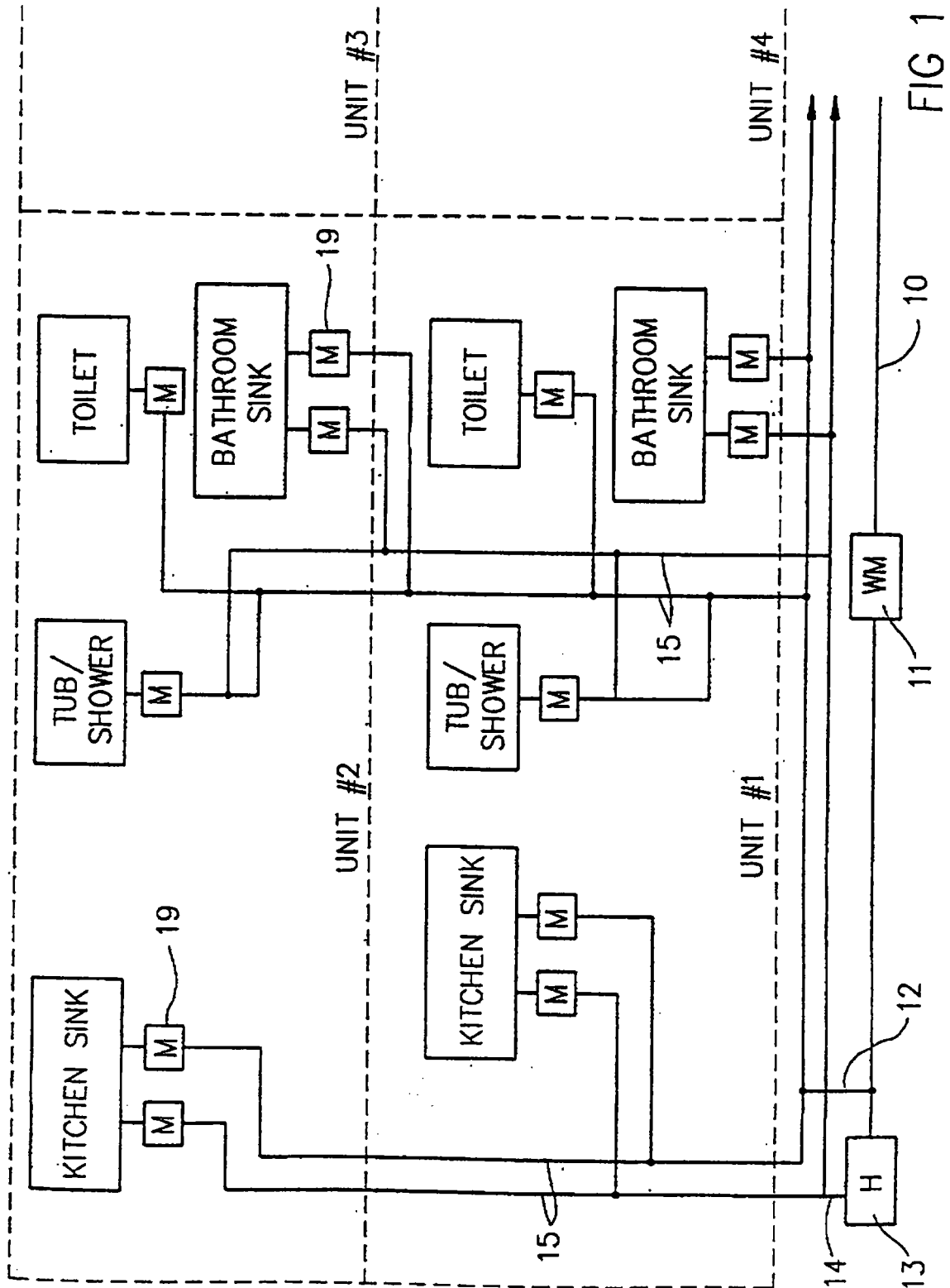
a host computer for receiving the total heat energy information from said remote receiver and computing a heat energy charge for the individual unit including the heat energy used by the device.

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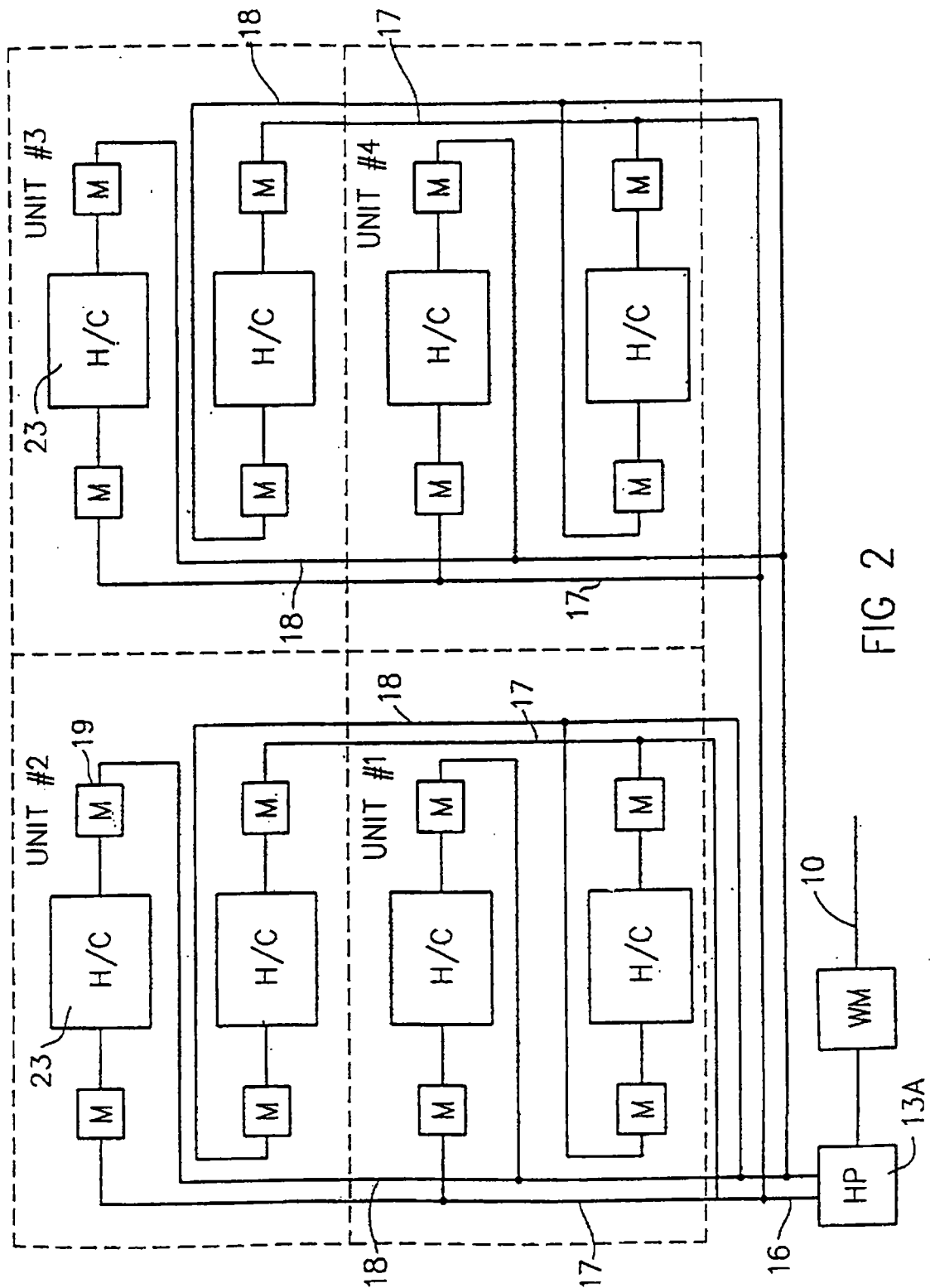


FIG 2

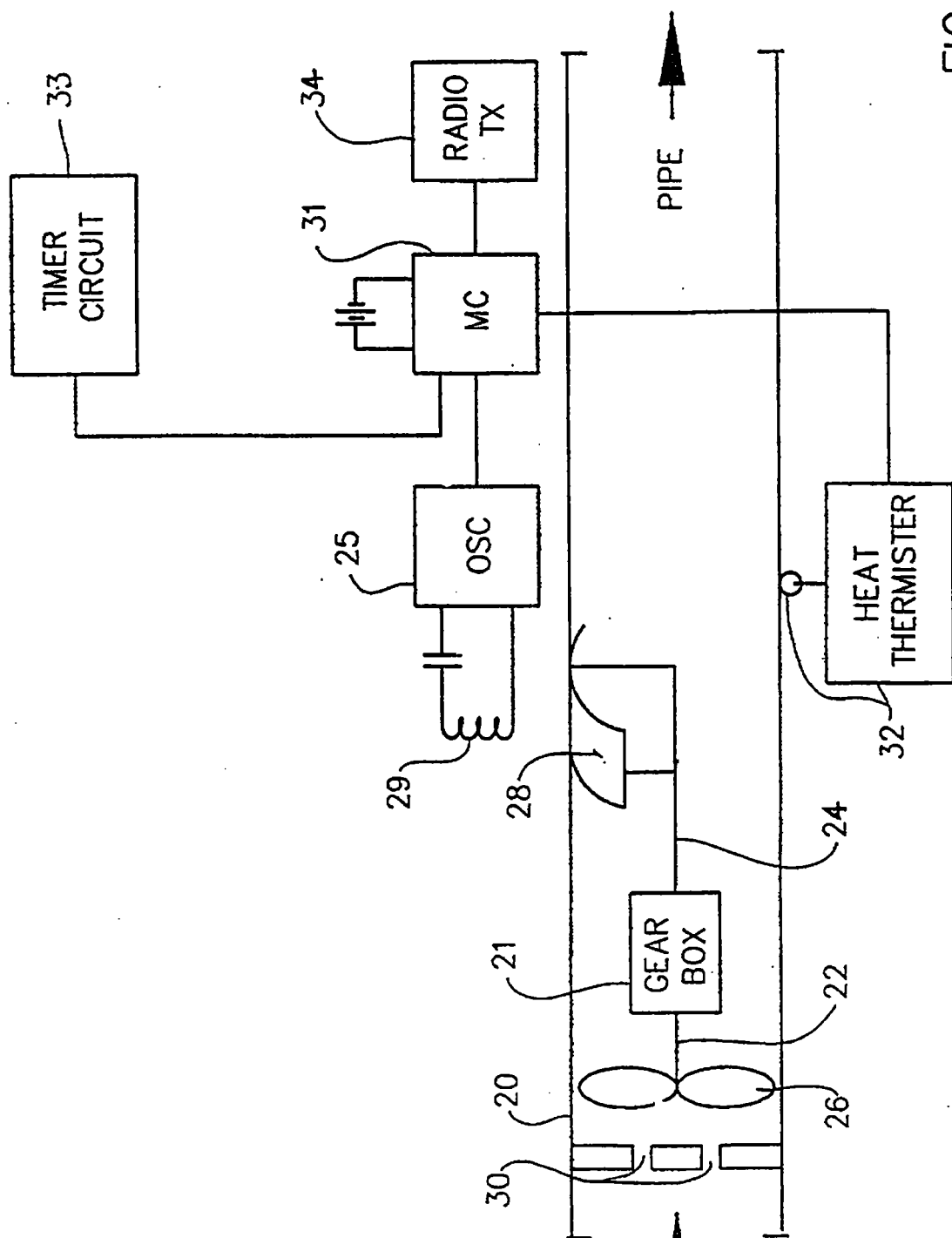


FIG 3

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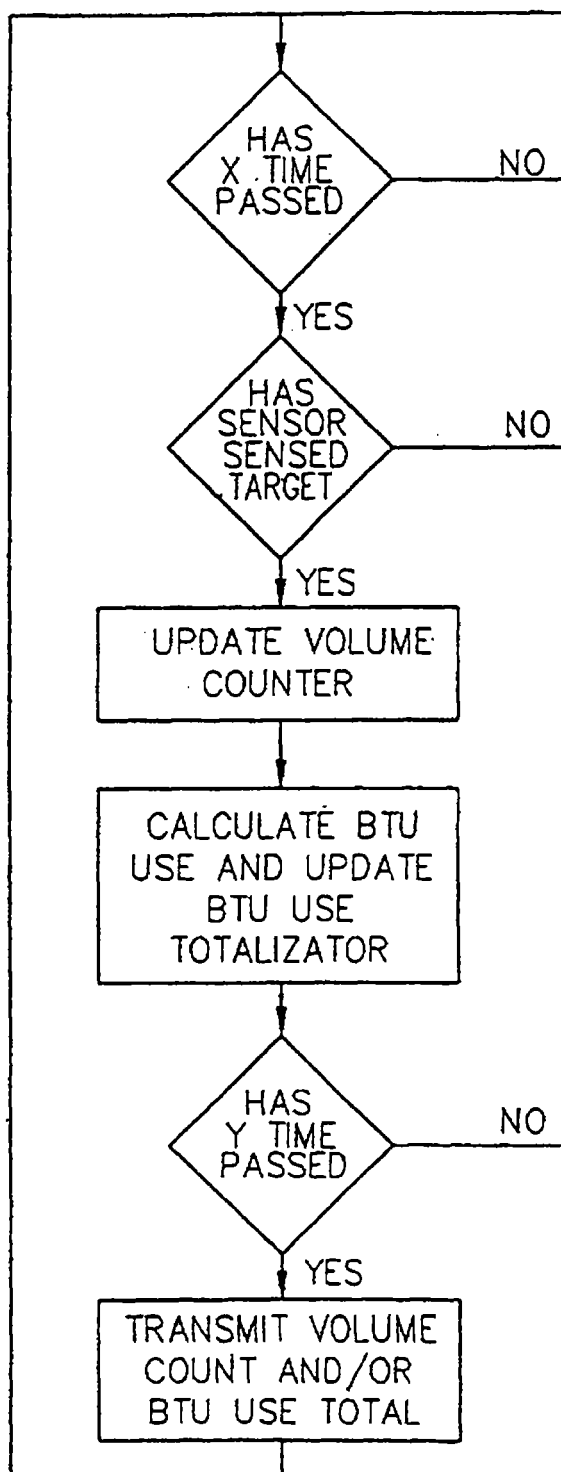


FIG 4

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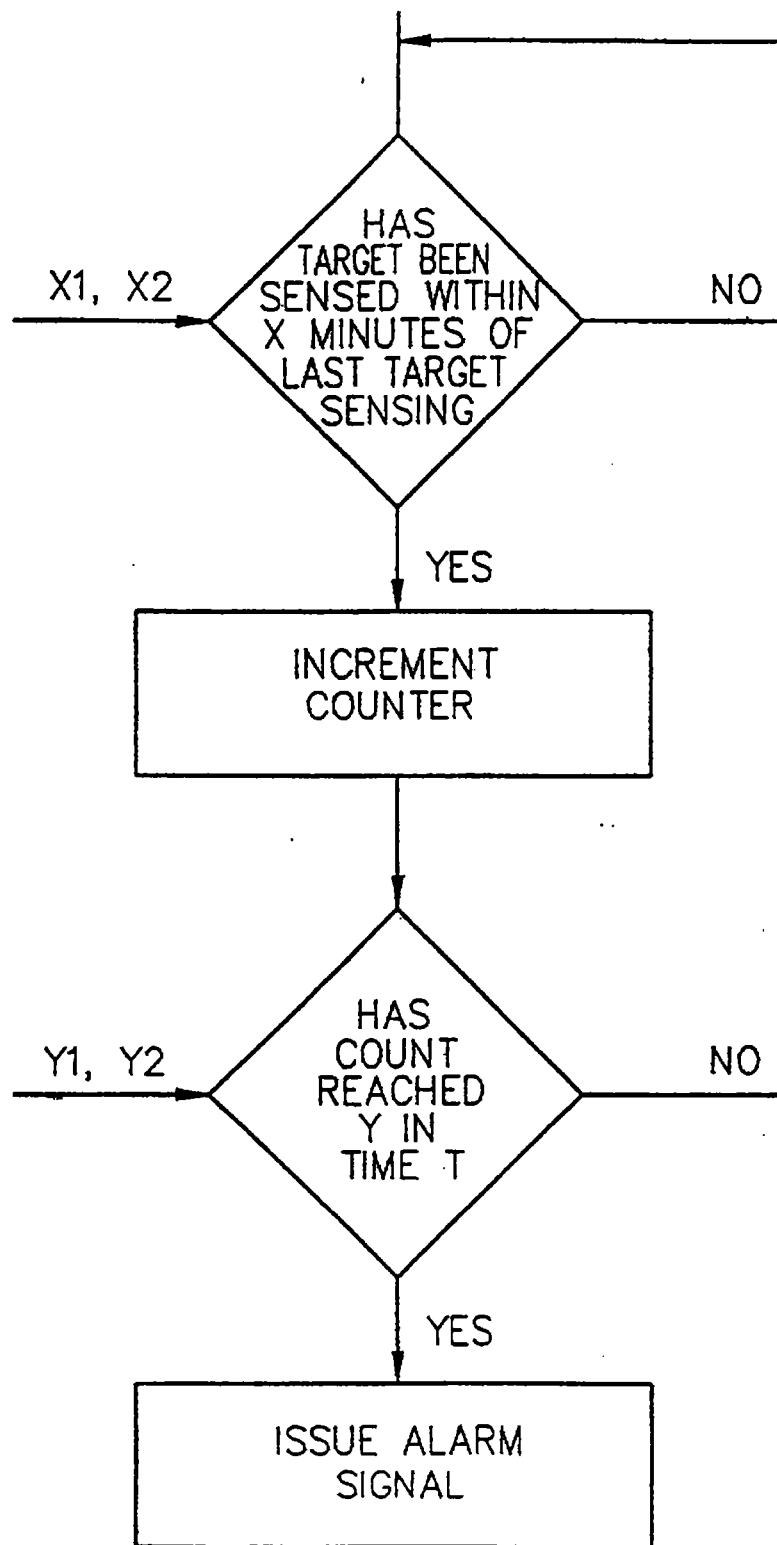


FIG 5

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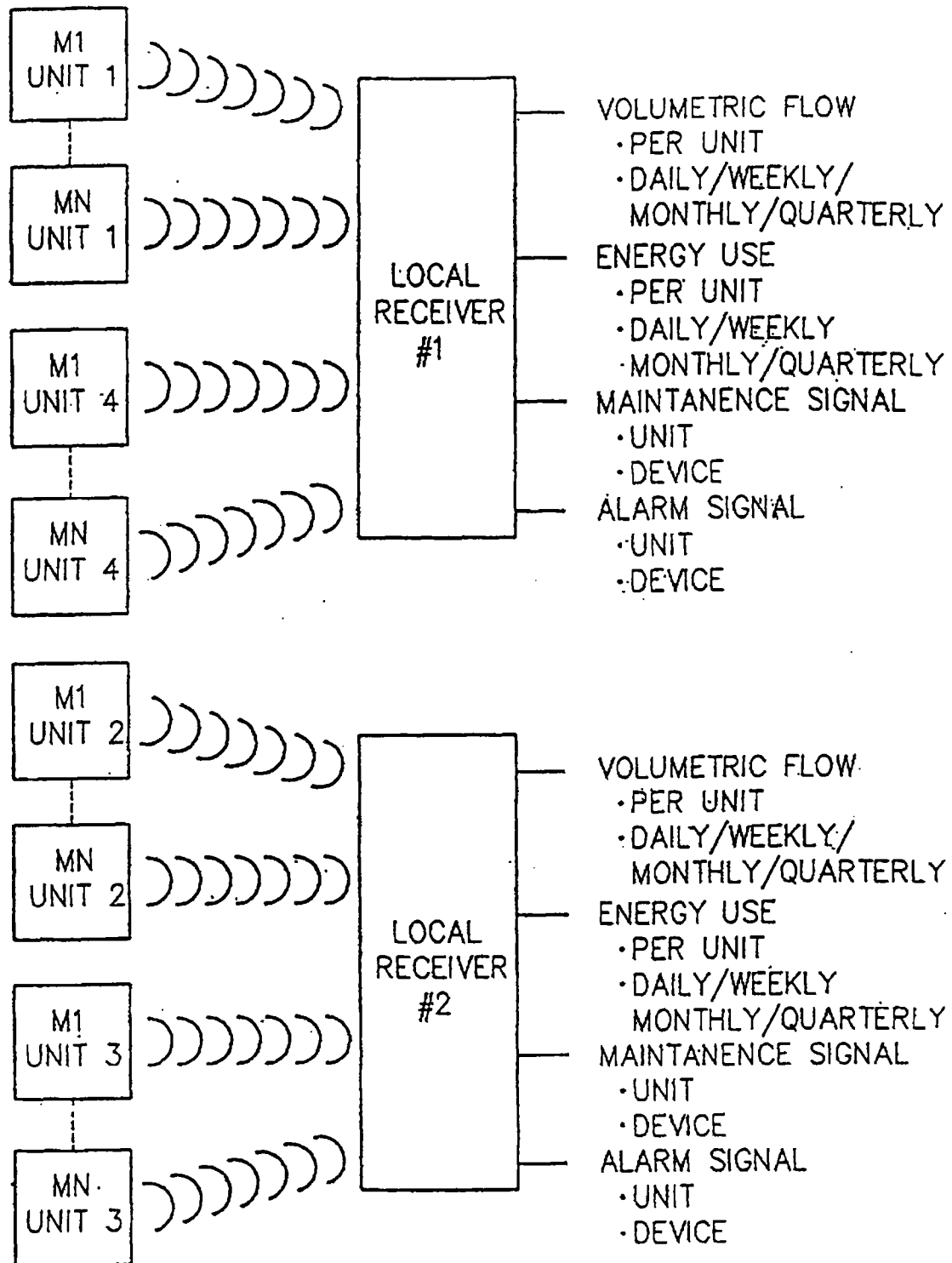


FIG 6

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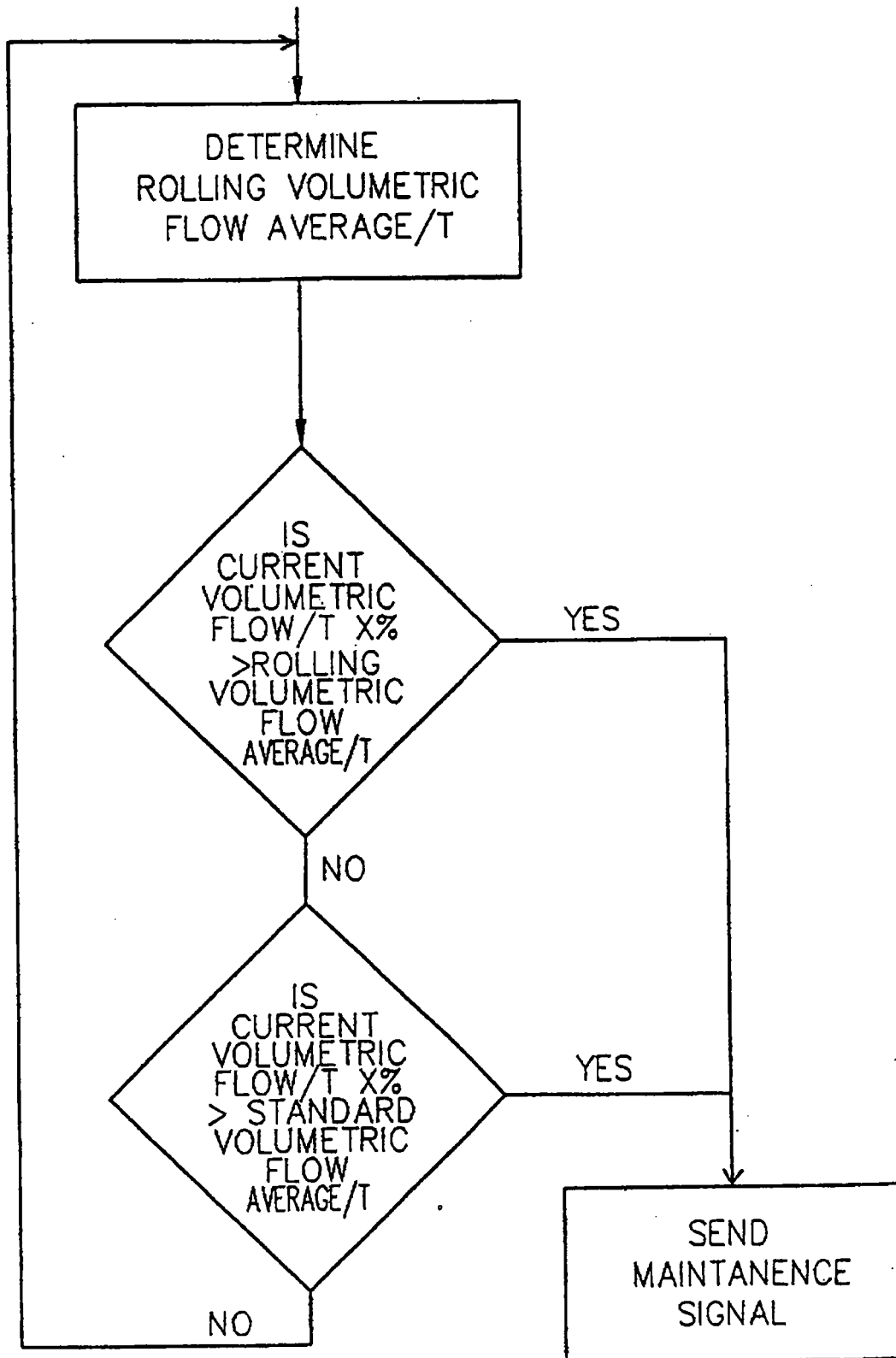


FIG 7

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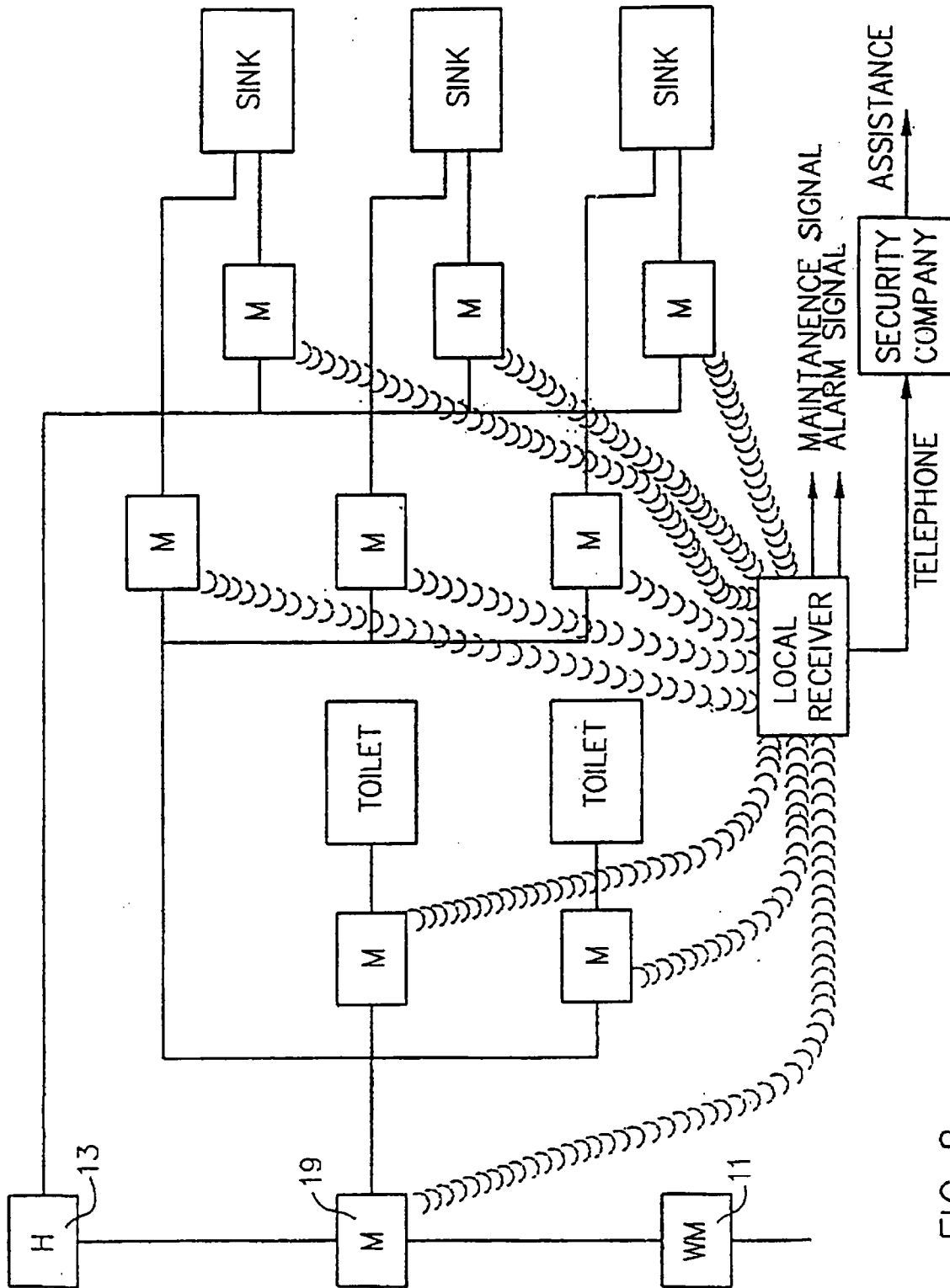
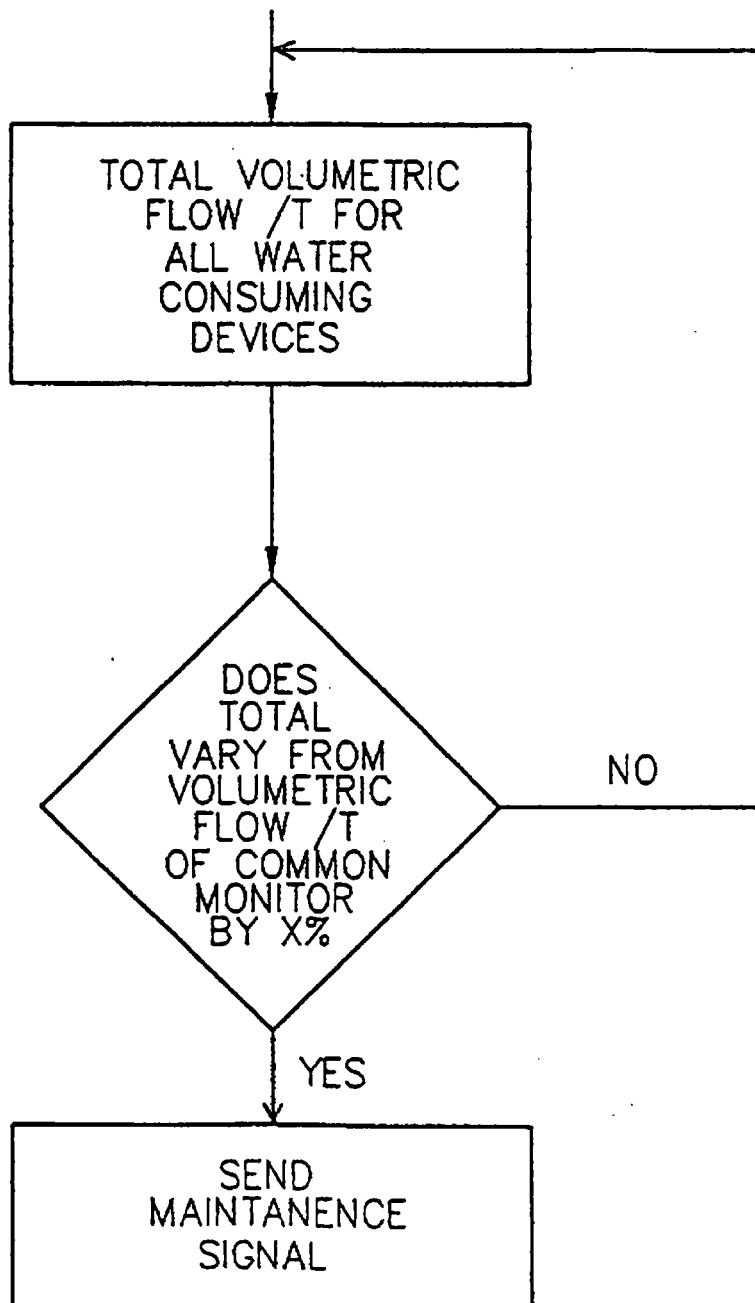


FIG 8

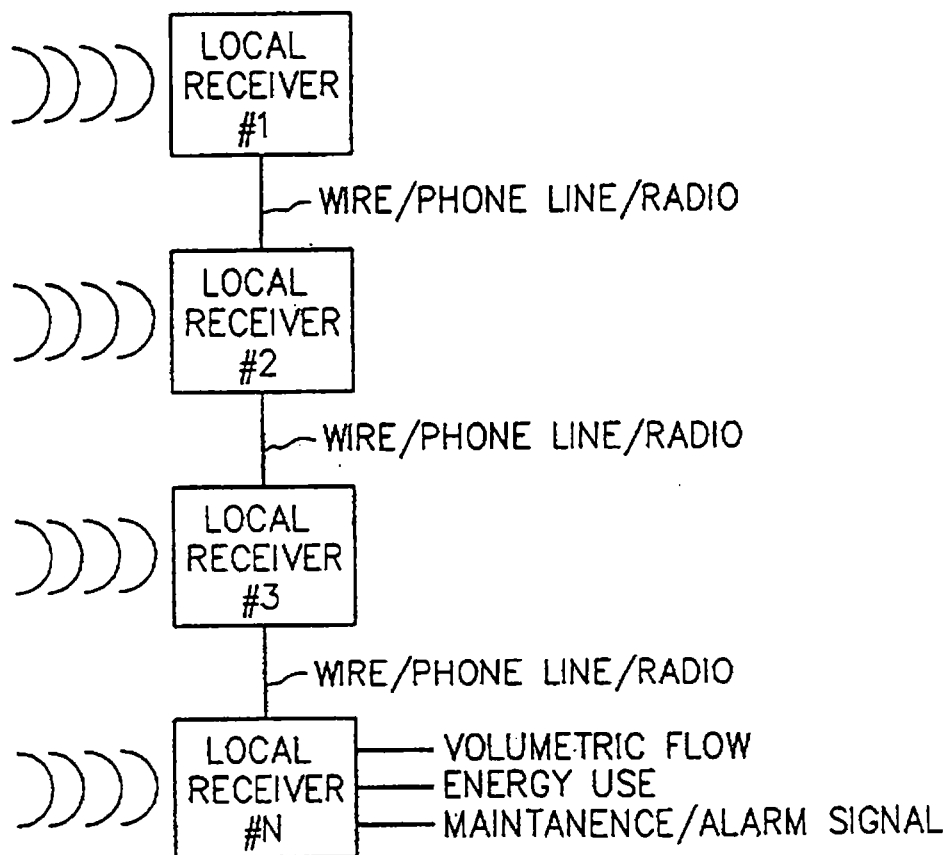


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FIG 9



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FIG 10

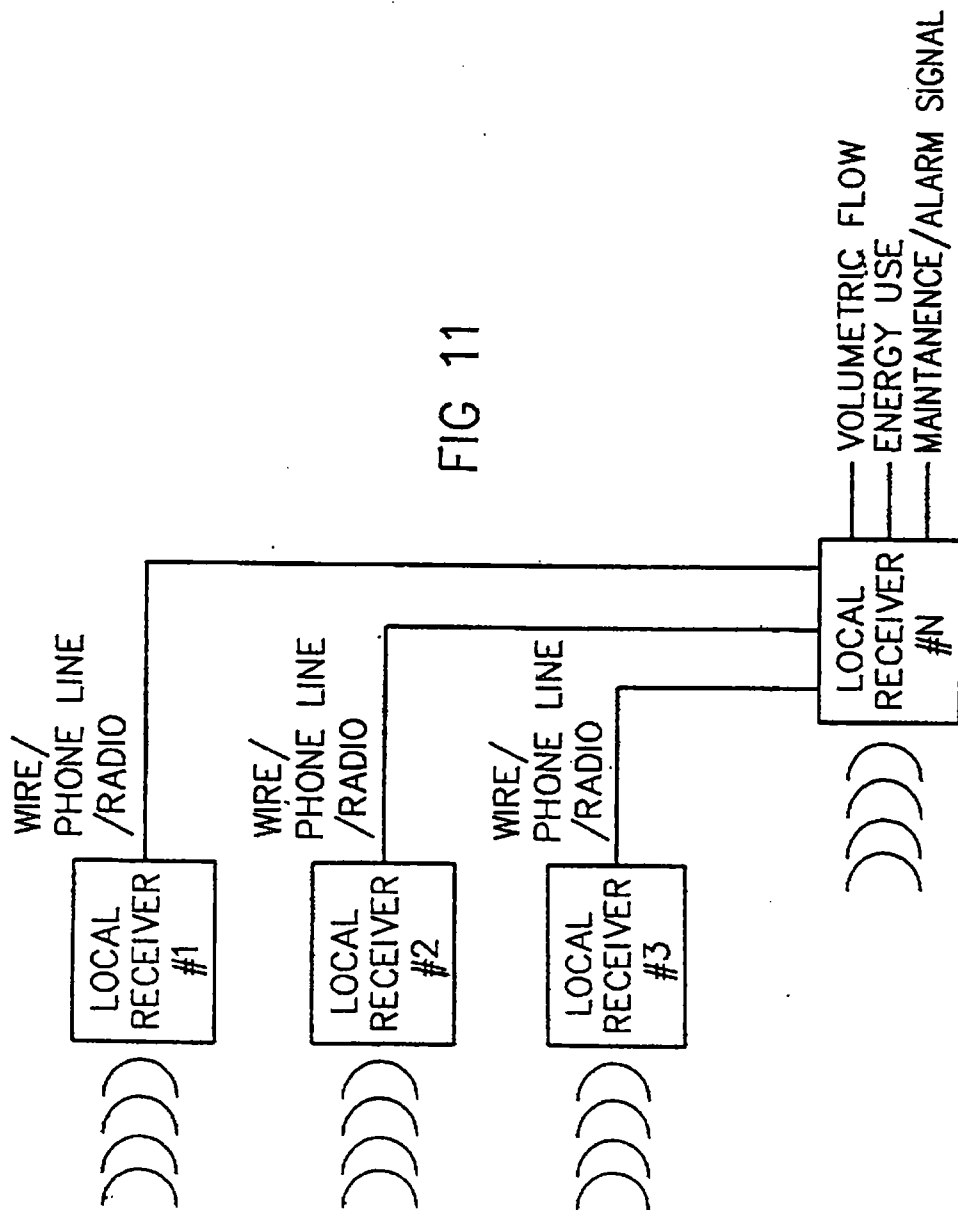


FIG 11

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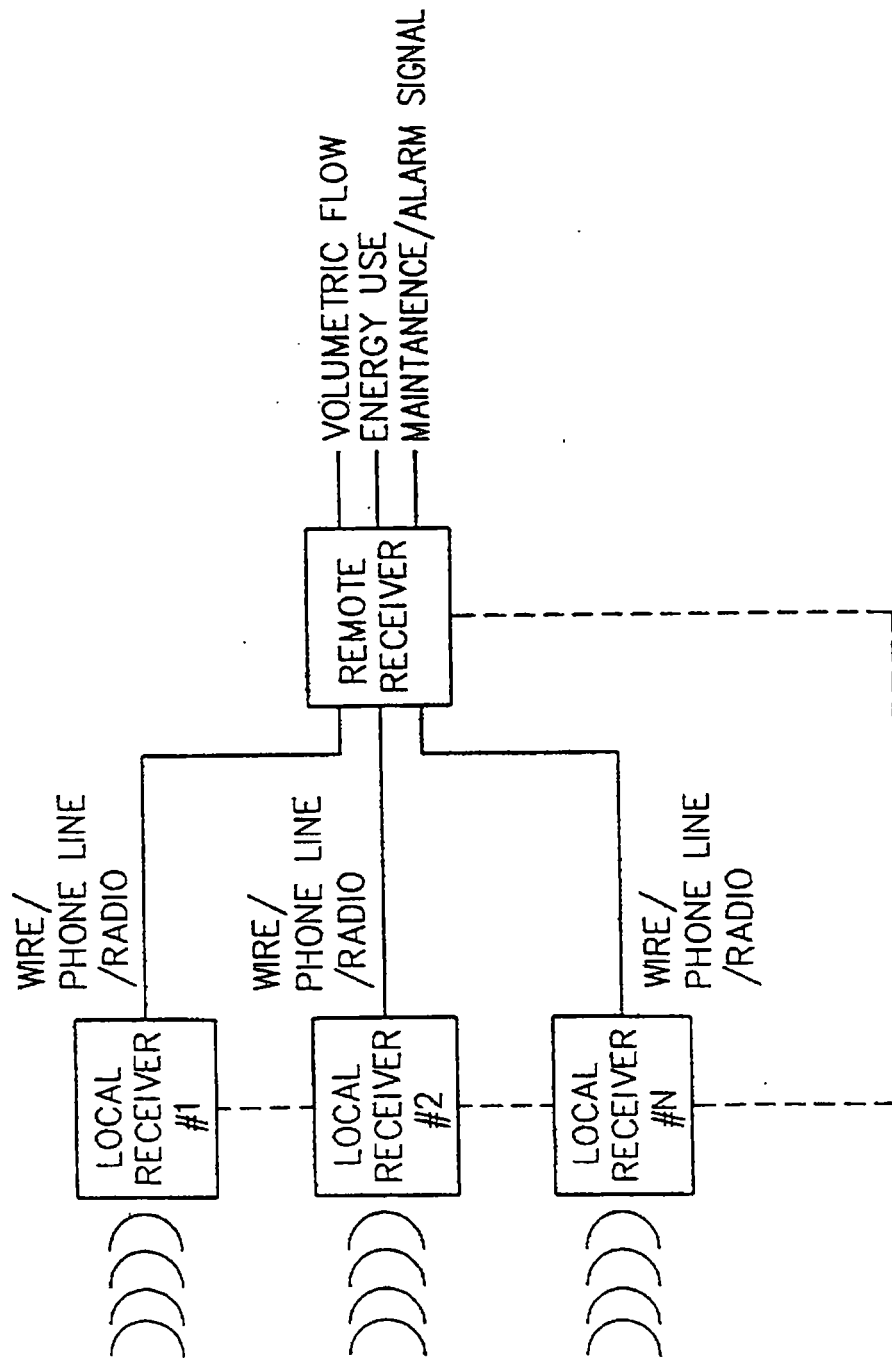


FIG 12

This is the replacement sheet

Date: 27 FEB 1992

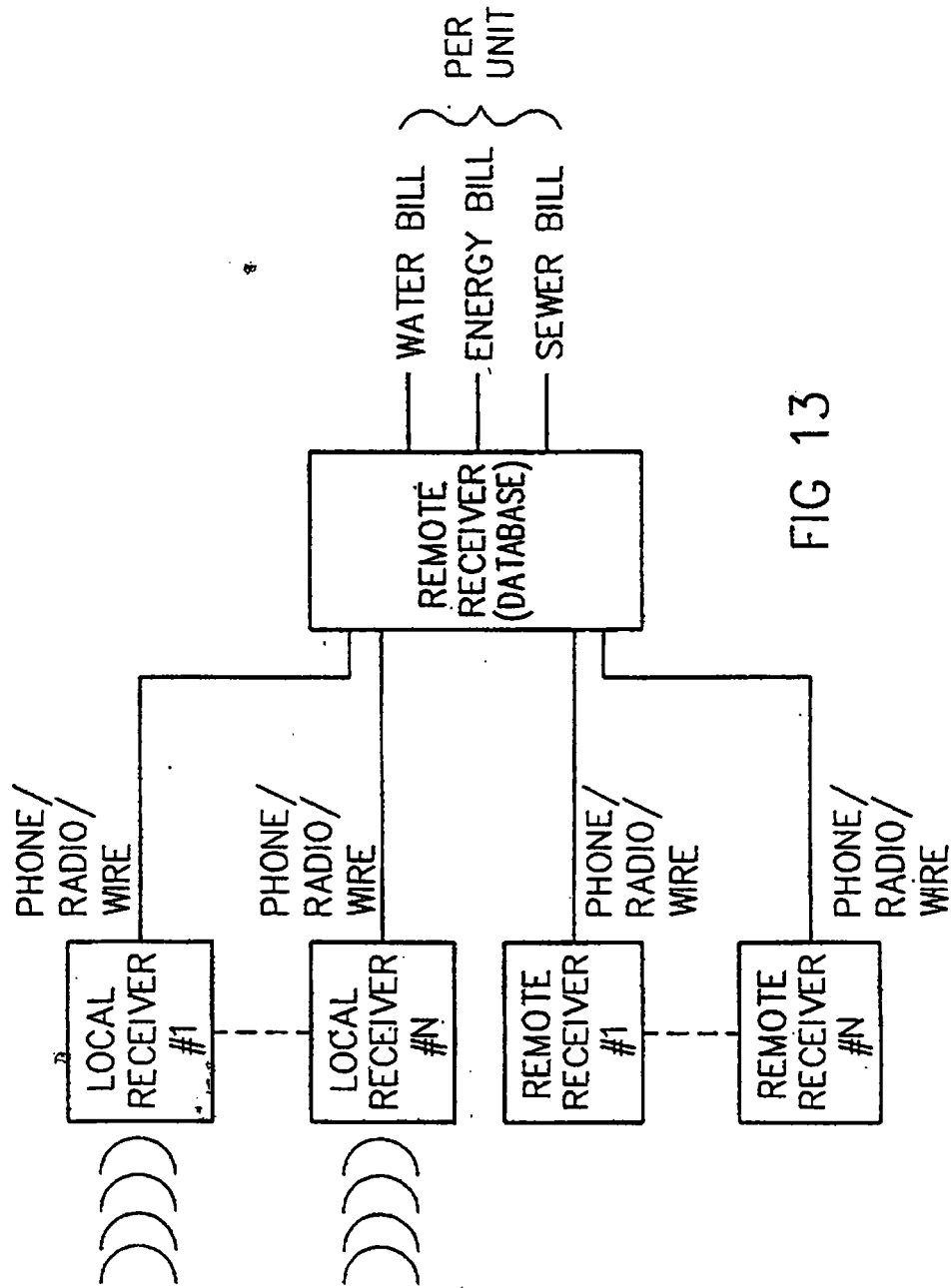


FIG 13

This is the replacement sheet

Date: 27 FEB 1998