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(54) **AUTOMOTIVE VEHICLE AND METHOD FOR CONTROLLING POWER CONSUMPTION OF A COMPRESSOR THEREIN**

(75) Inventors: **Susan Rebecca Cikanek**, Northville, MI (US); **William David Treharne**, Ypsilanti, MI (US); **Paul Stephen Bryan**, Belleville, MI (US); **David Jason Mack**, Plymouth, MI (US); **Melinda A. Mack**, legal representative, Plymouth, MI (US)

(73) Assignee: **Ford Global Technologies, LLC**, Dearborn, MI (US)

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CPC ***B60H 1/3208*** (2013.01); ***B60H 1/00392*** (2013.01); *B60H 2001/3273* (2013.01)

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CPC F04B 17/06; G06F 7/00; B60H 1/004; B60H 1/00385; B60H 1/00735; B60H 1/00271; B60H 1/3208; B60H 1/3216; B60H 1/3222; B60H 2001/3273; B60H 2001/3292
USPC 62/134, 228.1–230, 236, 244, 62/323.1–323.4; 165/41, 43; 303/152; 180/65.27; 307/66
See application file for complete search history.

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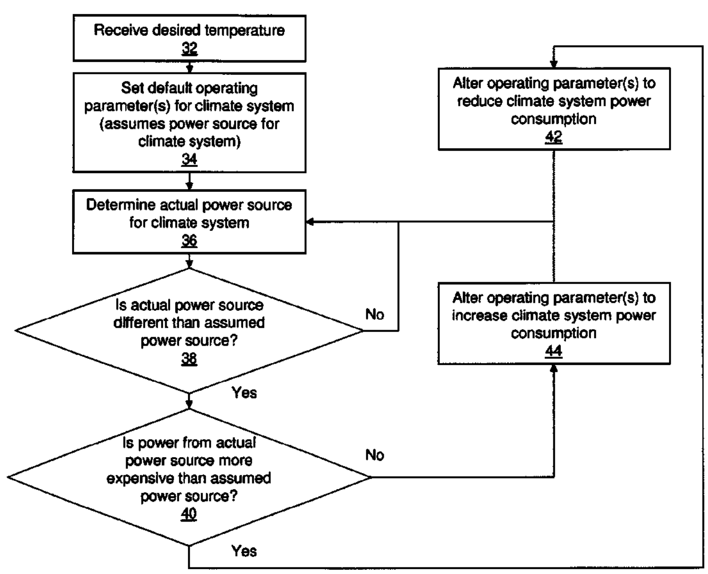
Primary Examiner — Travis Ruby
(74) *Attorney, Agent, or Firm* — David B. Kelley; Brooks Kushman P.C.

(57) **ABSTRACT**

A method for controlling power consumption of a compressor of an automotive vehicle climate system may include identifying an energy source providing energy to power the compressor and selecting an operating parameter of the climate system based on the identified energy source to control power consumption of the compressor.

2 Claims, 2 Drawing Sheets



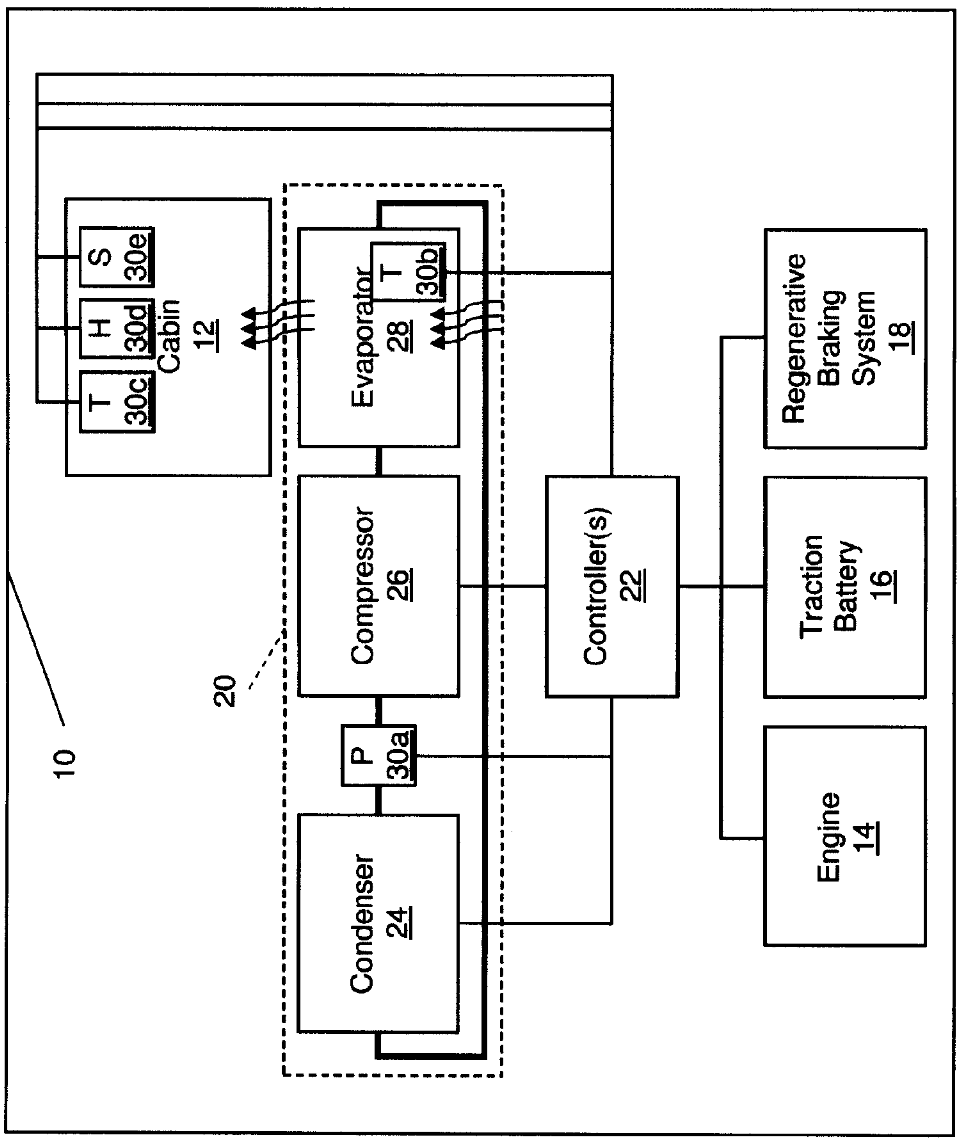

10
20
Cabin
12
T
30c
H
30d
S
30e
Evaporator
28
T
30b
Compressor
26
P
30a
Condenser
24
Controller(s)
22
Regenerative
Braking
System
18
Traction
Battery
16
Engine
14

Fig. 1

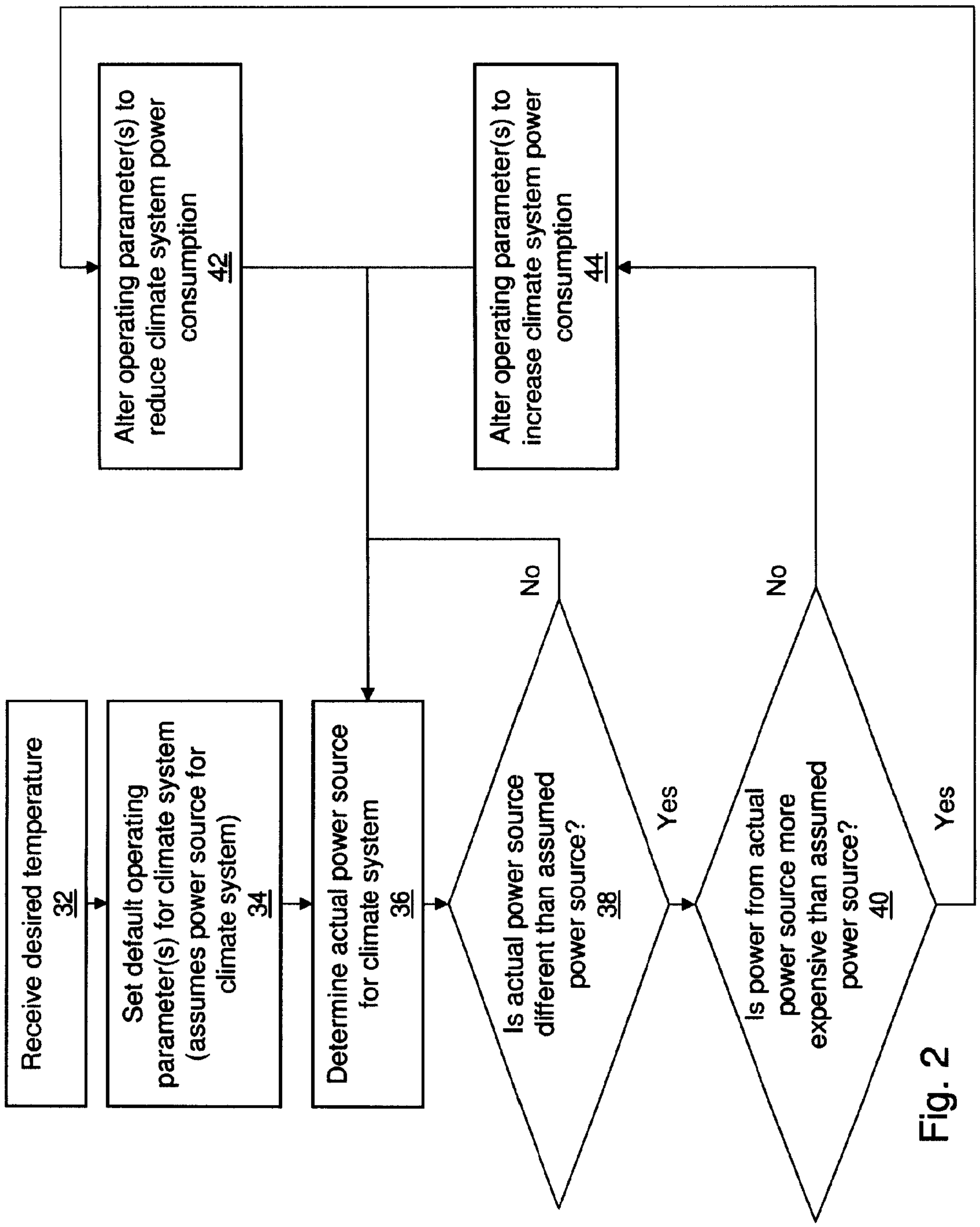

Receive desired temperature
32
Set default operating parameter(s) for climate system (assumes power source for climate system)
34
Determine actual power source for climate system
36
Is actual power source different than assumed power source?
38
Yes
No
Is power from actual power source more expensive than assumed power source?
40
Yes
No
Alter operating parameter(s) to reduce climate system power consumption
42
Alter operating parameter(s) to increase climate system power consumption
44

Fig. 2

AUTOMOTIVE VEHICLE AND METHOD FOR CONTROLLING POWER CONSUMPTION OF A COMPRESSOR THEREIN

BACKGROUND

An automotive climate control system may include a compressor that pressurizes and moves refrigerant through an evaporator. Such compressors operate to accommodate vehicle cabin cooling demands. Some compressors operate either at a full-on or full-off mode. That is, the speed of the compressor cannot be varied. Other compressors, such as electric air conditioning compressors, may operate at varied speeds.

SUMMARY

Power consumption of a vehicle climate control system's variable capacity compressor may be controlled by altering and/or selecting operating parameters for the climate system based on an energy source providing energy to power the compressor. The energy source may be an electrical power storage unit, a regenerative braking system, and/or an engine. The operating parameters may include a target evaporator temperature, maximum compressor speed, maximum compressor power, and/or controller response time.

While example embodiments in accordance with the invention are illustrated and disclosed, such disclosure should not be construed to limit the invention. It is anticipated that various modifications, alternative designs, and control methods including equivalents thereof may be made without departing from the scope of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block diagram of an embodiment of an automotive vehicle.

FIG. **2** is a flow chart depicting an example algorithm for controlling power consumption of the compressor of FIG. **1**.

DETAILED DESCRIPTION

Referring now to FIG. **1**, an automotive vehicle **10** may include a cabin **12**, engine **14**, power storage unit **16** (e.g., traction battery, ultra capacitor, etc.), regenerative braking system **18**, climate system **20** and one or more controllers **22**. The engine **14** and traction battery **16** may provide energy to move the vehicle **10**. The regenerative braking system **18** may capture energy from vehicle braking (active or coasting) for storage by the traction battery **16** and/or use by electrical devices within the vehicle **10**. In other embodiments, the vehicle **10** may be a plug-in battery electric vehicle, fuel cell vehicle, etc.

The climate control system **20** may include a condenser **24**, variable capacity compressor **26** (e.g., variable speed, variable displacement, belt driven electrically variable displacement, etc.), and evaporator **28**. Coolant may be circulated through the loop (shown in dark line) fluidly connecting the condenser **24**, compressor **26** and evaporator **28**. The coolant cools air (indicated by arrows) passing over the evaporator **28**. This air may be used to cool the cabin **12**.

The vehicle **10** further includes one or more sensors **30***n* (e.g., **30***a*-**30***e*). In the embodiment of FIG. **1**, the sensor **30***a* senses the pressure in the loop between the condenser **24** and compressor **26**. The sensor **30***b* senses the temperature of the evaporator **28**. The sensors **30***c*-**30***e* sense the temperature, humidity and sun load respectively in the cabin **12**. Other and or different sensors may also be used. Information from the sensors **30***n* is communicated to the one or more controllers **22**.

Cabin temperature is related to evaporator temperature:

$$\text{cabin temp.}=f(\text{evaporator temp.}). \tag{1}$$

Additionally, evaporator temperature is related to compressor speed:

$$\text{evaporator temp.}=f(\text{compressor speed}). \tag{2}$$

Hence, cabin temperature is related to compressor speed:

$$\text{cabin temp.}=f(\text{compressor speed}). \tag{3}$$

To achieve a desired cabin temperature (input by an occupant of the vehicle), a target evaporator temperature (and thus a corresponding compressor speed) may be selected by the one or more controllers **22**. Such targets may be established through testing, simulation, etc. The one or more controllers **22** may use a proportional-integral (PI) control scheme (or any other suitable control scheme) that determines the compressor speed based on a difference between the actual and target evaporator temperatures. The one or more controllers **22** may also limit compressor speed and compressor power, as known in the art.

Table 1 illustrates potential sources of energy to power the compressor **26**. The "cheapest" energy (the energy having the least impact on fuel economy) is listed at the top. The most "expensive" energy (the energy having the greatest negative impact on fuel economy) is listed at the bottom.

TABLE 1

Source
Regenerative Braking
Compression Braking
Engine, Low BSFC
Engine, High BSFC
Battery

Energy generated during regenerative braking is less expensive compared with energy generated during compression braking. Energy generated during compression braking is less expensive than energy generated by the engine **14** illustrated in FIG. **1**. Energy generated by the engine **14** running with low brake specific fuel consumption is less expensive than energy generated by the engine **14** running with high brake specific fuel consumption, etc. Hence, powering the compressor **26** with energy generated during regenerative braking will have the least impact on fuel economy. Powering the compressor **26** with energy taken from the traction battery **16** will have the greatest impact on fuel economy. (Assuming that energy stored in the traction battery **16** was generated, for example, by the engine **14** or through regenerative braking, and that losses occur while storing energy to and retrieving energy from the traction battery **16**.)

Referring now to FIGS. **1** and **2**, the operation of the compressor **26** may be controlled so as to influence the impact on fuel economy. At operation **32**, the one or more controllers **22** may receive a desired temperature input from an occupant of the vehicle **10**. The occupant, for example, may select 75° F. via a signal input device on an instrument panel of the vehicle **10**.

At operation **34**, the one or more controllers **22** may set default operating parameters for the climate system **20**. These parameters may include one or more of target evaporator temperature, maximum compressor speed, maximum compressor power, response time of the one or more controllers

22, etc. In some embodiments, the default operating parameter values may be set based on the desired temperature and the assumption that the source of power for the compressor **26** is compression braking. The target evaporator temperature, maximum compressor speed or displacement, etc. may be set aggressively (resulting in faster performance of the climate system **20**) as energy to power the compressor **26** is assumed to be relatively cheap.

In other embodiments, the default operating parameter values may be set based on the desired temperature and the assumption that the source of power for the compressor **26** is relatively expensive (resulting in slower performance of the climate system **20**). Generally speaking, lower target evaporator temperatures and shorter controller response times, as well as higher maximum compressor speeds and compressor power improve performance of climate systems. (Certain compressors, however, may be less efficient at high or low speeds.)

At operation **36**, the one or more controllers **22** may determine, in a known fashion, the actual power source for the compressor **26**. For example, the one or more controllers **22** may determine whether the energy to power the compressor is being generated by the engine **14**, traction battery **16** or regenerative braking system **18**.

At operation **38**, the one or more controllers **22** may determine whether the actual power source is different than the assumed power source. That is, the one or more controllers **22** may determine if the assumption regarding the cost of energy to power the compressor **26** is accurate given current vehicle circumstances. For example, the one or more controllers **22** may determine, in a known fashion, whether energy generated from compression braking is the actual source of power for the compressor **26** (in the case where compression braking is the assumed source of power). If no, the algorithm may end.

If the actual power source is different than the assumed power source, the one or more controllers **22** may determine, at operation **40**, whether energy from the actual power source is more expensive than energy from the assumed power source. For example, the one or more controllers **22** may determine, in a known fashion, that the engine **12** is generating energy to power the compressor **26** and that the engine **12** is running with high brake specific fuel consumption. As such, the relative cost of the energy to power the compressor **26** is more expensive than the assumed relative cost used to set the default operating parameter values (assuming that the default operating parameters were set with an assumption of relatively cheap energy, such as energy from compression braking, to power the compressor **26**). If no, the algorithm may end.

If energy from the actual power source is more expensive than energy from the assumed power source, the one or more controllers **22** may, at operation **42**, alter the operating parameter(s) of the climate system **20** to reduce the power consumption of the compressor **26** (at the expense of performance). Continuing with the example above, the one or more controllers **22** may raise the target evaporator temperature, increase its response time, decrease the limit on compressor speed and/or decrease the limit on compressor power. The amount by which the operating parameters are altered may be determined via testing, simulation, etc. and, in some embodiments, balance the desire to reduce power consumption with the performance expected/tolerated by vehicle occupants.

Returning to operation **40**, the one or more controllers **22**, if the energy from the actual power source is not more expensive (i.e., is less expensive) than energy from the assumed power source, may alter the operating parameter(s) of the climate system **20** to increase the power consumption of the compressor **26** (to improve performance). The one or more controllers **22**, for example, may lower the target evaporator temperature, decrease its response time, increase the limit on compressor speed and/or increase the limit on compressor power. Again, the amount by which the operating parameters are altered may be determined via testing, simulation, etc. and balance power consumption with performance.

In other embodiments, the one or more controllers **22** may access a look-up table having values for the climate system operating parameters mapped with the potential sources of energy for the compressor **26**. Before selecting the operating parameters for the climate system **20**, the one or more controllers **22** may determine, in a known fashion, the energy source for the compressor **26** and retrieve one or more operating parameters associated with that source from the look-up table. In such embodiments, default operating parameters may not be necessary. The one or more controllers **22** may periodically determine the energy source for the compressor **26** and retrieve/alter the appropriate operating parameters, etc. Other scenarios are also possible.

As apparent to those of ordinary skill, the algorithms disclosed herein may be deliverable to a processing device in many forms including, but not limited to, (i) information permanently stored on non-writable storage media such as ROM devices and (ii) information alterably stored on writeable storage media such as floppy disks, magnetic tapes, CDs, RAM devices, and other magnetic and optical media. The algorithms may also be implemented in a software executable object. Alternatively, the algorithms may be embodied in whole or in part using suitable hardware components, such as Application Specific Integrated Circuits (ASICs), state machines, controllers or other hardware components or devices, or a combination of hardware, software and firmware components.

While embodiments of the invention have been illustrated and described, it is not intended that these embodiments illustrate and describe all possible forms of the invention. Rather, the words used in the specification are words of description rather than limitation, and various changes may be made without departing from the spirit and scope of the invention.

What is claimed:

1. A vehicle comprising:

a battery;

an engine;

a regenerative braking system;

a climate system including a variable capacity compressor; and

a controller configured to alter a response time of the controller based on which of the battery, engine, and braking system is providing energy to power the compressor such that power consumption of the compressor is greater in response to the braking system providing energy to power the compressor as compared with the engine.

2. A method of operating a vehicle climate system including a variable capacity compressor comprising:

altering, by one or more controllers, a response time of the one or more controllers based on which of a power storage unit, engine, and braking system is providing energy to power the compressor such that power consumption of the compressor is greater in response to the braking system providing energy to power the compressor as compared with the engine.

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