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(54) **APPARATUS FOR REGULATING LENGTH OF COMPRESSOR CYCLES**

REGELGERÄT DER VERDICHTERPERIODENDAUER

APPAREIL DE REGLAGE DE LA LONGUEUR DE CYCLE D'UN COMPRESSEUR

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**FIELD OF THE INVENTION**

**[0002]** The invention relates in general to devices that consume electrical energy in the process of generating a cooling medium used for the purposes of reducing the temperatures within an area requiring reduced temperatures.

**[0003]** This invention is particularly suited to reducing power consumption in refrigeration and air conditioning units.

**[0004]** It is the purpose of this invention to reduce the electrical consumption of the electro-mechanical device (compressor) responsible for the generation of the cooling media, be it gas or liquid, that is being distributed throughout the area to be cooled/refrigerated. This reduction of electrical energy must be accomplished without the undesirable side-effect of causing temperature fluctuations, within the controlled environment, beyond those which existed before the installation of the invention.

**BACKGROUND OF INVENTION**

**[0005]** Air Conditioning/Cooling/Refrigeration systems (hereinafter "refrigeration systems" or "cooling systems"), which utilize compressors, are least efficient when starting up. Prior to reaching optimum running conditions, the average net BTU output of the refrigeration system is below its rated capacity. The optimum run conditions of a refrigeration system are not obtained until all of the component parts of the system have obtained their design operational temperatures. This can take considerable time after the compressor starts because the thermal inertia of each device, which was just off and is relatively hotter than when running, must be overcome. Some of the component parts of a refrigeration system are:

- a) Compressor
- b) Coolant-media (usually refrigerant gas).
- c) heat-exchangers:

the evaporator (the heat-exchanger used to absorb heat from the area to be cooled and transfer that heat to the coolant-media); and  
the Condenser, the heat-exchanger used to release heat from the coolant-media to the external ambient environment.

- d) Coolant-media piping,
- e) Items within the controlled space which have thermal mass and inertia,

**[0006]** US Patent 5,132,020, to Shah, col. 6 lines 18-54, refers to:

"Techniques for advancing and/or retarding the onset of change in setpoint temperature, .... if the plant (heating or cooling) is "off" and human intervention dictates a change in setpoint temperature which will cause the plant to go "on", then implementation of the requested setpoint changeover may be delayed until after the plant goes "on" under the current control setpoint. The magnitude of this delay will be equal to the duration of the last complete "off" period (previously defined as T3) minus the amount of time spent in the current "off" state (previously defined as T4).

**[0007]** But Shah refers to a delay in making a setpoint change, which may or may not coincide with a compressor call at the new setpoint. Shah does not teach directly delaying a compressor call as in the present invention. In Shah, the compressor call may come on, un-delayed, in spite of the delay in setpoint change. Shah does not teach using a delay to more efficiently regulate a steady-state temperature.

**[0008]** The invention increases the net BTU output of the refrigeration system by cycle control of the compressor. By intelligently increasing the delay between compressor run cycles, (the amount of which has been experimentally proven and to be within reasonable limits) longer more efficient (higher net BTU) output cycles are generated.

**[0009]** In connection with refrigeration systems, it is common knowledge that the output capacities of cooling systems are usually determined by:

- a) the worst case scenarios (design-loads) that the systems are expected to encounter.
- b) Anticipated future expansions.
- c) Expected degradation of the system output due to ageing.

**[0010]** Anytime the demand on the cooling system is less than the cooling capacity, the cooling system is over-sized. This "over-sizing" condition exists, within a typical properly designed system, about 85% of the time and causes the cooling system to cycle the compressor in an inefficient and energy consuming fashion.

**[0011]** There is another system scenario that the invention also addresses; that is one where the compressor is undersized and never shuts off. While it would seem that there is no way to save energy, other than to shut the compressor off, the invention does just that. After a predetermined amount of continuous run-time the compressor is stopped for a predetermined amount of time and then restarted. While it would appear to one skilled in the art that this would cause temperature fluctuations, in fact, experimentation with the present invention shows that it has less of an effect than that of a door being opened for that duration of time. The thermal inertia and thermal storage of the items within the controlled space are used, indirectly, as a capacitor of sorts to absorb these thermal transitions and they do just that,

**[0012]** It has also been proven experimentally that while extending the compressor off-time and subsequent lengthening of the on-time increases efficiency, there are certain limitations that the inventor feels must be addressed. In a properly sized refrigeration system (one that is cycling), extending the off-time beyond certain limits will cause temperature fluctuations and also will serve no useful purpose as far as energy reduction. Subsequently, the invention will not allow the extended off-time function to have any effect when the compressor has been off for longer than a predetermined time.

## **OBJECTS OF THE INVENTION**

**[0013]** The present invention seeks to:

- A) Reduce the electrical consumption of cooling/refrigeration systems by the modification of compressor run cycles.
- B) Provide compressor anti-short-cycling control to enhance compressor life expectancy and to further reduce electric consumption.

**[0014]** The invention, through the use of computer technology, is able to determine the thermodynamic loading imposed upon the compressor, without the need of any additional sensors, and to alter the compressor cycling pattern in such a fashion as to cause the cooling capacity of the system to more closely match the demand of the system. This more efficient ratio of capacity vs. demand causes a more efficient use of each compressor cycle and thereby a reduction of electric consumption.

**[0015]** It is well known in the industry about the effects of short-cycling a compressor. Short-cycling causes undue stress on the compressor as well as much greater than normal electrical demands due to locked-rotor conditions which can occur as a result of non-pressure-equalization within the compressor. This condition is caused by an insufficient time-lapse between when the compressor is stopped and then restarted. Another factor of short-cycling is the excess heat buildup in the motor windings which can be caused by repeated rapid starting of the compressor. To this end, the invention incorporates an anti-short-cycling algorithm as part of its program.

**[0016]** It is therefore desirable for the invention to be an energy saving device capable of being used in cooling energy value sensor (such as a thermostat or pressuretrol) demand type control systems. It is not limited to such applications, but would also be suited for use with energy management systems. This invention would be suitable for new, retrofit and original equipment manufacturer (OEM) installations. It is also the invention's intent to be simple to install and not require any programming or adjustments.

## **BRIEF DESCRIPTION OF THE DRAWINGS**

**[0017]**

Figure 1A is a diagrammatic representation of a typical refrigeration systems, using Thermostat control.

Figure 1B is a diagrammatic representation of a typical refrigeration systems, using pressure control.

Figure 2 is a typical installation wiring diagram.

Figure 3 is an electronic schematic.

Figure 3A is another embodiment of the schematic of Figure 3.

Figure 4 is a chart graphing system vs. load characteristics with and without the invention.

Figure 5 is a chart graphing compressor cycling pattern for given load, with and without the invention, portraying cycle reduction with the invention.

Figure 6 is a chart graphing compressor cycle pattern with and without the invention illustrating the maximum on-time effect of the invention on the compressor cycling when the compressor would not normally cycle.

Figure 7 is a chart graphing compressor cycles with and without the invention, displaying the effect of the anti-short-cycling algorithm.

#### **DETAILED DESCRIPTION OF THE DRAWINGS**

**[0018]** Figure 1A, shows a refrigeration system, generally designated 2, which includes the present invention. The system comprises a compressor 4, which pumps high pressure gas through high pressure pipe 6 to condenser 8. Fan 10 is propelled by motor 12, and drives air 14 across condenser 8 to cool the condenser coils 9, and the gas therein, causing the gas to condense to liquid and give up its heat of condensation. Through the length of the condenser 8, large amounts of heat are lost to cooling air 14, which brings down the temperature and heat content of the media leaving the condenser, bringing said media to a liquid state. The liquid media is driven by pressure and it flows from condenser 8 through liquid pipe 16.

**[0019]** Liquid media flows along the liquid pipe 16, to evaporator 18, where fan 20, driven by motor 22, drives hot air 24 to be cooled by the evaporator 18. The liquid media from liquid pipe 16, in evaporator 18 absorbs heat from the air 24, and the media evaporates, absorbing the heat of evaporation, and exits along low pressure gas pipe 26, returning to compressor 4, which again drives it through its cycle via high pressure gas pipe 6.

**[0020]** Energy value sensor, thermostat 28 controls fan motor 22, by closing a relay 29 between current source 30 and fan motor 22. Absent the invention, thermostat 28 would simultaneously close relay 31 between current 32 and compressor 4, so that current could flow across relay 31 and would actuate power compressor 4.

**[0021]** However, control apparatus 34 of the present invention interrupts the connection 36, which provides voltage to relay 31, and thereby prevents the compressor 4 from turning on. This results in a delay, which is controlled according to the program outlined further below.

**[0022]** In figure 1B, control apparatus 34 is interposed in the wire 39 between the compressor 4 and energy value sensor, which is pressuretrol 40. Pressuretrol 40 is typically found as the temperature equivalent sensor on a refrigeration unit. A program also provides an appropriate delay to increase efficiency.

**[0023]** Figure 2 is a typical installation wiring diagram which shows a control unit 34 of the present invention, wired into the cooling circuit. Figure 2 shows control circuit power 42, which may be 230, 115 or 24 volts AC in the embodiment shown depending on which contact 44 a, b, or c it is attached to. Wires 44-46 supply control circuit power to control unit 34.

**[0024]** The same voltage is supplied across existing thermostat 28 or pressuretrol 40. Control wire 36 or 39 would provide control voltage to compressor contactor relay 31, but is broken so that yellow wire 48 and blue wire 49 insert control unit 34 into the circuit to prevent the compressor from operating until an appropriate delay has intervened.

**[0025]** Figure 3 is a more detailed circuit diagram of the control unit 34. AC power is supplied by wires white 44 and brown 46 to transformer 47, then to rectifier 50, comprising four ring diodes, which rectifies the AC to DC. Approximately 14 volt DC is output across smoothing capacitor 56 to voltage regulator 57 across bypass capacitor 58 to pin 1 of BS-1. BS-1 distributes 12 volts DC to control circuit 60 and its micro-controller chips 61 and memory 62 via voltage regulating chip 63 and power-on reset chip 64. Light Emitting Diode 101 (LED) indicates mode status. LED 102 indicates if an energy value sensor is calling for compressor. Optoisolator 104 provides a sensor call to the controller over a wide range of possible call voltages, making this unit well suited for a variety of cooling systems.

**[0026]** While the units presently being tested are shown in figure 3, the inventor has constructed a unit using fewer of the chips which are now available. Cost may vary but the units are electronically equivalent, where a single chip replaces chips 61 and 62, and chips 63 and 64 are eliminated. See Fig. 3A. Further variations may be constructed by appropriately using component manufacturers' specifications to create equivalents. It will be understood that the best mode of constructing the controller will vary with the availability and capability of new chip designs.

**[0027]** Controller 34 operates according to the computer program at the end of this specification, entitled "COOLING ROUTINE".

**[0028]** The program incorporates a 180 second anti-short-cycling delay to always avoid starting the compressor within 180 seconds of compressor shut down. This is sufficient time to reduce undue stress on the compressor, as well as much greater than normal electrical demands, due to locked-rotor conditions, by allowing pressure-equalization within the compressor. A 180 second rest reduces excess heat buildup in the motor windings which heat can be caused by repeated rapid starting of the compressor. An anti-short-cycling algorithm tests off-time against the program constant

MINOFFTIME, before allowing the compressor to start.

**[0029]** If the compressor off-time has been greater than 1 hour, the compressor is started immediately upon a call for cooling, the counter is reset, and a new count begins.

**[0030]** If off-time has not been greater than an hour, the delay is calculated as 10% of the last off time, and a countdown for that interval from the sensor call continues. Once the countdown ends, the compressor relay actuates the compressor, and a new timecount starts.

**[0031]** The compressor continues running until:

the sensor call ends, which starts a new off-time count; or

a substantial run time elapses, sufficient to bring the space to be cooled to equilibrium, such as an hour, at which time the compressor is given a short rest, but sufficient to allow compressor pressure equalization and compressor motor cooling, such as a 6 minute rest, before restarting.

**[0032]** Figure 4 graphs the difference between:

standard compressor on/off time cycles, and  
the compressor on/off time cycles with the present invention,

under three different load conditions: loads A, B, and C.

**[0033]** These graphs also show the response of the compressor to varying temperature or pressure depending on whether the cooling system is controlled by a thermostat or a pressuretrol.

**[0034]** Without the invention T1, T6 and T11 represent points on the temperature or pressure graphs that correspond to points when the compressor is started. T3, T8 and T13 correspond to the temperature or pressure levels when the compressor is stopped.

**[0035]** With the invention T2, T7, and T12 correspond to the new temperature or pressure compressor start points. T4, T9 and T14 correspond to the respective longer intervals before the compressor stop points. T0-T1, T5-T6 and T10-T11 are the time intervals from the last compressor shut-down to a point when there is a need for cooling, hereinafter the off-call-time.

**[0036]** T0-T2, T5-T7, and T10-T12 are the new off-intervals required due to the invention, including the invention's extended off-intervals of T1-T2, T6-T7 and T11-T12.

**[0037]** Figure 5 graphs the effect of a load, over seven cycles of a conventional cooling system, without the present invention (top). As can be seen on the bottom of figure 5, the same load is handled in only five on-cycles, with reduced on-time, with the present invention. Temperature excursions beyond the high point are insignificant and brief. The graph also illustrates the compressor response either to temperature or cooling media pressure, depending on whether the energy value sensor is a thermostat or a pressuretrol.

**[0038]** Where T1 represents the compressor turn-on point along the temperature or pressure curves without the invention, T2 represents the new turn-on point and includes the extended off-time T1-T2, with the invention, T3 corresponds to the turn-off point of the temperature or pressure curves without the invention; T4 with the invention.

**[0039]** Figure 6 graphs a saturation load. Without the invention, the compressor runs continuously. The invention gives the compressor a 6 minute rest (T3-T4; T5-T6; etc.) every 54 minutes (T2-T3, T5-T6, etc.), to cool down, to save energy in the brief off-time. Temperature (not graphed) is largely unaffected by this rest period.

**[0040]** Figure 7 graphs a short cycle restart without the invention. The T1-T2 interval is too short to equalize compressor pressure or to cool the motor coils. A severe and power consuming electrical load results, that might even burn out the motor.

**[0041]** With the invention, the short compressor off-time (T1-T2) is extended by T2-T3 to an adequate 3 minutes (T1-T3), resulting in an easier starting load on the motor.

**[0042]** All the above time values are optimized in this presently preferred embodiment, but it will be appreciated that advantages of this invention can be achieved in spite of various departures from the above time and percentage values.

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'COPYRIGHT 1997 JACK N. HAMMER
,
,
5 'THERMOMISER PROGRAM
'COOLING ROUTINE
'12/27/96
,
'rev 1
10 '6/19/97 changed from 2 leds to 1
'rev 2
'8/29/97 added max ON-TIME, OFF-TIME, OFF TIME, AND ANTI SHORT-CYCLING.
,
'*****SYMBOLS - CONSTANTS*****
SYMBOL TRUE = 1
15 SYMBOL FALSE = 0
SYMBOL ON = 1
SYMBOL OFF = 0
SYMBOL NOT_ON = 0
SYMBOL NOT_OFF = 1
SYMBOL FLAG_REG = B0 'FLAG BYTE, CONTAINS BITS B0 - B7
20 SYMBOL COUNT = BIT0 'USED AS A SECOND (TIME) GENERATOR XOR'D WITH 1
SYMBOL MULTCNT = BIT1 'set when a percent delay has been calculated
SYMBOL DWNCNTFLAG = BIT2 'set when counting down for delay
SYMBOL MINOFFFLAG = BIT3 'rev2 -- flag for anti-short-cyclind set when ok to run
'SYMBOL BYPASSFLAG = BIT4 'not used
25 SYMBOL LED1 = PIN1 'pin used to control led
'SYMBOL LED2 = PIN2 'rev.1
SYMBOL CALL4COOLIN = PIN6 'input sense when call for compressor
SYMBOL COOLOUT = PIN7 'relay control pin
SYMBOL COUNTER = W1 'reg used for counting up & down
SYMBOL PERCOUNTER = W2 'temp reg for percent calculation
30 SYMBOL MULTLIM = W3 'reg used for multiplier upper limit
SYMBOL PERCENT_DELAY = 10 'used for delay time mutiplier factor
SYMBOL OFFTIME = 360 'rev2 -- 360 forced off cycle time
SYMBOL MAXONTIME = 3240 'rev2 -- max on time (seconds) before forcing off
SYMBOL MAXOFFTIME = 3600 'rev2 -- max off time (seconds) causing instant on
SYMBOL MAXCOUNTER = W4 'rev2 -- word used for on-time counter
35 SYMBOL MINOFFTIME = 180 'rev2 -- 180 anti-short cycling time delay

'INITIALIZE VARIABLES
DIRS=310000110 'SETS PINS 1,2 AND 7 FOR OUTPUT
COOLOUT = NOT_OFF 'ENERGIZES RELAY
40 COUNTER = 0: PERCOUNTER = 0 'RESETS FLAGS TO KNOWN STATE
MAXCOUNTER = 0 'rev2 - set to known value
MULTLIM = 65535 / PERCENT_DELAY 'set multlim to value, used in off time
calculation
FLAG_REG = FALSE 'resets all flags
PAUSE 450 'delay
45 '*****main routine*****
MAIN:
PAUSE 450 'loop time delay used for timing
COUNT = COUNT ^ 1 'generates seconds
IF CALL4COOLIN = NOT_ON AND MINOFFFLAG = TRUE THEN MAINTTEST' rev2
50 ' rev2 IF CALL4COOLIN = NOT_ON THEN MAINTTEST
MINOFFFLAG = FALSE' rev2

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IF DWNCNTFLAG = TRUE THEN ZEROCNTR
COOLOUT = NOT_OFF
'LED1 = ON 'rev.1
5 'LED2 = OFF 'rev.1
'led1 = off 'rev.2
led1 = call4cooln ^ 1' rev2 reverses led blink during anti short cycle
pulsout 1,5000 'pulses led
MULTCNT = FALSE
GOSUB COUNTUP 'counts up during comtressor off time
10 GOTO MAIN

'***** main test *****
'this loop is jumped to when there is a need for cooling
MAINTEST:
IF COUNTER>MAXOFFTIME THEN STARTNOW 'rev2 -- if greater than 1 hr. start
15 IF MULTCNT = FALSE THEN MULTIPLY 'tests for delay calculation
IF MAXCOUNTER>MAXONTIME THEN OFFCYCLE 'rev2 -- tests for long on-time
IF COUNTER = 0 THEN COOLON 'if delay has expired, start compressor
GOSUB COUNTDWN 'counts down when in delay mode
GOTO MAIN
20 '*****

'calculates delay time
MULTIPLY:
MULTCNT = TRUE
25 IF COUNTER > MULTLIM THEN MULTIPLY2 'this makes sure that the result can not
exceed 65535
PERCOUNTER = COUNTER * PERCENT_DELAY / 100
COUNTER = PERCOUNTER
GOTO MAIN
MULTIPLY2:
30 PERCOUNTER = COUNTER / 100 * PERCENT_DELAY
COUNTER = PERCOUNTER
GOTO MAIN

COOLON:
COOLOUT = NOT_ON
35 rem LED1 = OFF
rem LED2 = ON
led1 = on
GOSUB MAXTIMECOUNT 'rev2
GOTO MAIN

40 ZEROCNTR:
DWNCNTFLAG = FALSE
COUNTER = 0
GOTO MAIN

COUNTUP:
45 IF MINOFFFLAG = FALSE AND COUNTER > MINOFFTIME THEN SETMINOFFFLAG 'rev2
COUNTER = COUNTER + COUNT MAX 65534
RETURN

SETMINOFFFLAG:
50 MINOFFFLAG = TRUE
GOTO COUNTUP:

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COUNTDOWN:
DWCNTFLAG = TRUE
LED1 = COUNT
5   COUNTER = COUNTER - COUNT
    COUNTER = COUNTER MIN 0
    PAUSE 50
    RETURN

10  MAXTIMECOUNT: 'rev2
    MAXCOUNTER=MAXCOUNTER + COUNT 'rev2
    RETURN 'rev2

    OFFCYCLE: 'rev2
    COOLOUT = NOT OFF 'rev2
15  COUNTER = OFFTIME 'rev2
    MAXCOUNTER = 0 'rev2
    led1 = OFF 'rev2
    GOTO MAIN 'rev2

20  STARTNOW: 'rev2 causes compressor on by putting counter to 0 and multcnt
    COUNTER = 0 ' true.  this fools the program into thinking that the unit
    MULTCNT = TRUE ' went thru a normal cycle.
    GOTO MAINTTEST 'rev2

```

## Claims

1. A method of regulating a cooling system (2) operation, comprising the steps of:

30 measuring an off-call-time (Fig. 5 T0 to T1) of a compressor (4) control circuit (34) for the purpose of delaying the application of power to the compressor (4);  
sensing a compressor (4) call (Fig. 5 T1) from an energy value sensor (28); and always preventing the operation of the compressor (4) for an interval (Fig. 5 T1 to T2) which is a value derived from the measured off-call-time (Fig. 5 T0 to T1), and not less than a minimum off-time (Fig. 7 T1 to T3).

2. A method according to claim 1, in which operation of the compressor (4) is prevented unless and until the off-call-time (Fig. 7 T1 to T2) exceeds a predetermined value (Fig. 7 T1 to T3), which value allows for substantial compressor (4) pressure equalization.

3. A method according to claim 1, further comprising the steps of:

40 storing the off-call-time (Fig. 5 T0 to T1) last measured in a memory;  
calculating a percentage of the off-call-time;  
preventing compressor (4) operation for a delay (Fig. 5 T1 to T2) equal to the percentage; and  
45 operating the compressor (4) subsequent (Fig. 5 T2 to T4) to the delay (Fig. 5 T1 to T2).

4. A method according to claim 1, further comprising the steps of:

50 measuring an on-cycle (Fig. 6 T1 to T15) of compressor (4) operation time; stopping operation of the compressor (4) after the on-cycle has extended for a substantial on-time interval (Fig. 6 T2 to T3); and  
the step of interrupting operation of the compressor (4) is for a measured off-time of a rest interval (Fig. 6 T3 to T4), which rest interval is short but sufficient to allow:

55 compressor (4) equalization,  
compressor (4) motor cooling, and  
efficiency resulting from the rest interval (Fig. 6 T3 to T4), which is brief, during which a space temperature is substantially maintained by a thermal inertia of any cooled objects and fluids in the space.

5. A method of regulating a cooling system (2) according to claim 1, said method comprising the steps of:

monitoring a value from an energy value sensor (28);  
determining from said value whether the value warrants a call for compressor (4) operation;  
5 generating a call when warranted (Fig. 7 T2);  
measuring an off-call-time prior to said call from a previous compressor (4) shut down (Fig. 7 T1-T2);  
storing the off call-time (Fig. 7 T1 to T2) last measured in a memory;  
in which the minimum off-time (Fig. 7 T1 to T3) would allow substantial compressor (4) pressure equalization;  
10 calculating a percentage of the off-call-time;  
the value derived from the measured off-call time (Fig. 5 T0 to T1) is equal to the percentage;  
operating the compressor (4) subsequent to the interval;  
measuring an on-cycle (Fig. 6 T1 to T15) of compressor (4) operation time; interrupting operation of the compressor (4) after the on-cycle has extended for a substantial interval (Fig. 6 T2 to T3) sufficient to bring a space to an equilibrium temperature; and  
15 preventing operation of the compressor (4) for a predetermined rest interval (Fig. 6 T3 to T4), which rest interval is short but sufficient to allow:

compressor (4) equalization,  
compressor (4) motor cooling, and  
20 improving efficiency by saving energy during the rest interval (Fig. 6 T3 to T4),  
during which rest interval a thermal inertia of any cooled objects and fluids in the space substantially maintains a temperature in the space.

6. A method according to claim 5, in which a following set of optimal values are substantially used:

the minimum off-time (Fig. 7 T1 to T3) is three minutes; the percentage is ten percent;  
the substantial interval (Fig. 6 T2 to T3) is 54 minutes; and the predetermined rest interval (Fig. 6 T3 to T4) is 6 minutes.

7. A cooling system (2) comprising a compressor (4), a cooling media, and a heat exchanger, further comprising:

an energy value sensor (28); and  
means:

35 for monitoring the energy value sensor (28),  
for controlling the compressor (4),  
for determining the thermal load on the cooling system (2),  
for measuring an off-call-time (Fig. 5 T0 to T1) of a compressor (4) control circuit (34),  
for receiving a compressor (4) call from the energy value sensor (28), and  
40 for always preventing the energy value sensor (28) from running the system compressor (4) for an interval (Fig. 5 T1 to T2) which is a value derived from the measured off-call-time.

8. Apparatus according to claim 7, in which the controlling means includes:

45 a break in a power supply wire (36 or 39) between:

the energy value sensor (28), and  
the compressor (4); and  
50 means (34) for switchably bridging said break.

9. Apparatus according to claim 8 in which the means for monitoring the energy value sensor (28) comprises:

a hot wire (36 or 39) switched on by the energy value sensor (28) in response to an energy value at which the space requires more cooling; and switch means (104) for actuation by a voltage on the hot wire (36 or 39).

10. Apparatus according to claim 9 in which the switch means (104) for actuation by a voltage on the hot wire (36 or 39) is an electronic circuit (104) for sensing a wide range of voltage inputs.

11. Apparatus according to claim 10 in which the wide range of voltage inputs is between 24 VAC and 240 VAC.

12. Apparatus according to claim 10 in which the electronic circuit comprises an optoisolator (104).

5 13. Apparatus according to claim 10 in which the electronic circuit comprises a microcontroller (60).

14. Apparatus according to claim 13 with means:

10 for increasing a run-time per cycle of the compressor (4), and thereby  
for improving electric utilization and for decreasing a total run-time of the compressor(4).

15. Apparatus according to claim 7 in which the energy value sensor is a thermostat (28).

16. Apparatus according to claim 7 in which the energy value sensor is a pressuretrol (40).

15 17. Apparatus according to claim 8 in which the switch means (31) is in a normally closed position so that, if the power supply (42) or controller (34) fail, the cooling system (2) still operates.

20 18. A method according to claim 1 wherein, if the compressor (4) off-call-time (Fig. 5 T0 to T1) has been greater than a maximal value, the interval is substantially zero.

19. A method according to Claim 18, in which the maximal value is substantially an hour.

## 25 Patentansprüche

1. Ein Verfahren zum Regeln des Betriebs eines Khlsystems (2), aufweisend die Schritte:

30 Messen einer Ausschaltungs-Anforderungs-Zeitdauer (Figur 5 T0-T1) einer Steuerschaltung (34) eines Verdichters (4) zum Zwecke des Verzgerns des Bereitstellens von Energie an den Verdichter (4);  
Erfassen einer Verdichter (4) Anforderung (Figur 5 T1) von einem Energiewert-Sensor (28); und jederzeitiges Verhindern des Betriebs des Verdichters (4) fr ein Intervall (Figur 5 T1-T2) welches einen von der gemessenen Ausschaltungs-Anforderungs-Zeitdauer (Figur 5 T0-T1) abgeleiteten Wert hat, und nicht krzer als eine minimale Ausschaltungs-Zeitdauer (Figur 7 T1-T3) ist.

35 2. Ein Verfahren gem Anspruch 1, wobei der Betrieb des Verdichters (4) verhindert wird, sofern nicht und bis die Ausschaltungs-Anforderungs-Zeitdauer (Figur 7 T1-T2) einen vorgegebenen Wert (Figur 7 T1-T3) berschreitet, wobei der Wert ermglicht, dass im Verdichter (4) ein betrchtlicher Druckausgleich stattfindet.

40 3. Ein Verfahren gem Anspruch 1, ferner die Schritte aufweisend:

Speichern der zuletzt gemessenen Ausschaltungs-Anforderungs-Zeitdauer (Figur 5 T0-T1) in einem Speicher;  
Berechnen eines Prozentanteils der Ausschaltungs-Anforderungs-Zeitdauer;  
Verhindern des Betriebs des Verdichters (4) fr eine Verzgerung (Figur 5 T1-T2), die gleich dem Prozentanteil  
45 ist; und  
Betreiben des Verdichters (4), nachfolgend (Figur 5 T2-T4) zu der Verzgerung (Figur 5 T1-T2).

4. Ein Verfahren gem Anspruch 1, ferner aufweisend die Schritte:

50 Messen eines Einschalt-Zyklus (Figur 6 T1-T15) der Betriebsdauer des Verdichters (4);  
Anhalten des Betriebs des Verdichters (4) nachdem der Einschalt-Zyklus sich ber ein betrchtliches Einschalt-Zeitintervall (Figur 6 T2-T3) erstreckt hat; wobei der Schritt des Unterbrechens des Betriebs des Verdichters (4) fr eine gemessene Ausschalt-Zeit eines Ruhe-Intervalls (Figur 6 T3-T4) erfolgt, wobei das Ruhe-Intervall  
kurz ist, jedoch ausreichend lang, um zu erlauben, dass:

55 ein Ausgleich des Verdichters (4) erfolgt,  
eine Motorabkhlung des Verdichters (4) erfolgt, und

wobei die Effizienz von dem Ruhe-Intervall (Figur 6 T<sub>e</sub>-T<sub>4</sub>) resultiert, welches kurz ist und während dessen eine Raumtemperatur im Wesentlichen durch eine thermische Trägheit jedes gekühlten Objekts und jedes Fluids in dem Raum gehalten wird.

- 5 5. Ein Verfahren zum Regeln eines Kühlsystems (2) gemäß Anspruch 1, wobei das Verfahren die Schritte aufweist:

Überwachen eines Wertes von einem Energiewertsensor (28);  
Bestimmen aus dem Wert, ob der Wert eine Anforderung des Betriebs des Verdichters (4) rechtfertigt;  
Erzeugen einer Anforderung, sofern gerechtfertigt (Figur 7 T<sub>2</sub>);  
10 Messen einer Ausschaltungs-Anforderungs-Zeitdauer, vor der Anforderung von einer vorhergehenden Abschaltung des Verdichters (4) an (Figur 7 T<sub>1</sub>-T<sub>2</sub>);  
Speichern der Ausschaltungs-Anforderungs-Zeitdauer (Figur 7 T<sub>1</sub>-T<sub>2</sub>), welche zuletzt gemessen wurde, in einem Speicher;  
wobei die minimale Ausschaltungs-Zeitdauer (Figur 7 T<sub>1</sub>-T<sub>3</sub>) ermöglicht, dass in dem Verdichter (4) ein beträchtlicher Druckausgleich erfolgt;  
15 Berechnen eines Prozentanteils der Ausschaltungs-Anforderungs-Zeitdauer;  
wobei der von der gemessenen Ausschaltungs-Anforderungs-Zeitdauer (Figur 5 T<sub>0</sub>-T<sub>1</sub>) abgeleitete Wert gleich dem Prozentanteil ist;  
Betreiben des Verdichters (4) nach der Zeitdauer (Intervall);  
20 Messen eines Einschalt-Zyklus (Figur 6 T<sub>1</sub>-T<sub>15</sub>) einer Betriebszeit des Verdichters (4);  
Unterbrechen des Betriebs des Verdichters (4) nachdem der Einschalt-Zyklus sich für ein beträchtliches Intervall (Figur 6 T<sub>2</sub>-T<sub>3</sub>) erstreckt hat, welches ausreicht, um einen Raum auf eine Gleichgewichtstemperatur zu bringen; und  
Verhindern des Betriebs des Verdichters (4) für ein vorgegebenes Ruhe-Intervall (Figur 6 T<sub>3</sub>-T<sub>4</sub>), wobei das  
25 Ruhe-Intervall kurz ist, jedoch ausreichend, um zu erlauben:

dass ein Ausgleich in dem Verdichter (4) eintritt,  
dass eine Motorabkühlung in dem Verdichter (4) eintritt, und

30 wobei die Effizienz durch Einsparung von Energie während des Ruhe-Intervalls (Figur 6 T<sub>3</sub>-T<sub>4</sub>) verbessert wird, wobei während des Ruhe-Intervalls eine thermische Trägheit jedes gekühlten Objekts und Fluids in dem Raum im wesentlichen die Temperatur in dem Raum erhält.

- 35 6. Ein Verfahren gemäß Anspruch 5, wobei im Wesentlichen der nachfolgende Satz von optimalen Werten verwendet wird:

die minimale Ausschalt-Zeit (Figur 7 T<sub>1</sub>-T<sub>3</sub>) beträgt 3 Minuten;  
der Prozentanteil beträgt 10 Prozent;  
das beträchtliche Intervall (Figur 6 T<sub>2</sub>-T<sub>3</sub>) beträgt 54 Minuten; und  
40 das vorgegebene Ruhe-Intervall (Figur 6 T<sub>3</sub>-T<sub>4</sub>) beträgt 6 Minuten.

7. Ein Kühlsystem (2) mit einem Verdichter (4), einem Kühlmedium und einem Wärmetauscher, ferner aufweisend:

45 einen Energiewertsensor (28); und  
Mittel:

zum Überwachen des Energiewertsensors (28),  
zum Steuern des Verdichters (4),  
zum Bestimmen der thermischen Last auf das Kühlsystem (2),  
50 zum Messen einer Ausschaltungs-Anforderungs-Zeitdauer (Figur 5 T<sub>0</sub>-T<sub>1</sub>) einer Verdichter(4)-Steuerschaltung(34),  
zum Empfangen einer Verdichter(4)-Anforderung von dem Energiewertsensor (28), und  
zum jederzeitigen Verhindern des Betriebes des System-Verdichters (4) durch den Energiewertsensor (28) für ein Intervall (Figur 5 T<sub>1</sub>-T<sub>2</sub>), welches einen Wert hat, der von der gemessenen Ausschaltungs-Anforderungs-Zeitdauer abgeleitet ist.  
55

8. Vorrichtung gemäß Anspruch 7, wobei die Steuermittel aufweisen:

eine Unterbrechung in einer Energieversorgungsleitung (36 oder 39) zwischen:

dem Energiewertsensor (28) und  
dem Verdichter (4) ; und  
Mitteln (34) zum schaltbaren Überbrücken der Unterbrechung.

9. Vorrichtung gemäß Anspruch 8, wobei die Mittel zum Überwachen des Energiewertsensors (28) aufweisen:

einen heißen Draht (hot wire) (36 oder 39), welche durch den Energiewertsensor (28) in Reaktion auf einen  
Energiewert geschaltet wird, bei dem der Raum mehr Kühlung erfordert ; und  
Schaltmittel (104) zur Betätigung durch eine Spannung auf dem heißen Draht (36 oder 39).

10. Vorrichtung gemäß Anspruch 9, wobei die Schaltmittel (104) zur Betätigung durch eine Spannung auf dem heißen  
Draht (36 oder 39) eine elektronische Schaltung (104) zum Erfassen eines breiten Bereichs von Eingangsspannun-  
gen sind.

11. Vorrichtung gemäß Anspruch 10, wobei der weite Bereich von Eingangsspannungen zwischen 24 VAC und 240  
VAC liegt.

12. Vorrichtung gemäß Anspruch 10, wobei die elektronische Schaltung einen Optoisolator (104) aufweist.

13. Vorrichtung gemäß Anspruch 10, wobei die elektronische Schaltung einen Mikrocontroller (60) aufweist.

14. Vorrichtung gemäß Anspruch 13, mit Mitteln:

zum Erhöhen einer Laufzeit-Pro-Zyklus des Verdichters (4) und dadurch zum Verbessern der elektrischen  
Nutzung und zum Verringern der gesamten Betriebszeit des Verdichters (4).

15. Vorrichtung gemäß Anspruch 7, wobei der Energiewertsensor ein Thermostat (28) ist.

16. Vorrichtung gemäß Anspruch 7, wobei der Energiewertsensor ein Pressuretrol (40) ist.

17. Vorrichtung gemäß Anspruch 8, wobei die Schaltmittel (31) in Normalstellungen in einer geschlossenen Stellung  
sind, so dass das Kühlsystem (2) weiterhin arbeitet, wenn die Energieversorgung (42) oder der Controller (34)  
ausfallen.

18. Ein Verfahren gemäß Anspruch 1, wobei dann, wenn die Ausschaltungs-Anforderungs-Zeitdauer (Figur 5 T0-T1)  
des Verdichters (4) größer als ein maximaler Wert ist, das Intervall im wesentlichen Null beträgt.

19. Ein Verfahren gemäß Anspruch 18, wobei der maximale Wert im wesentlichen eine Stunde ist.

## Revendications

1. Procédé de régulation du fonctionnement d'un système de refroidissement (2), comprenant les étapes consistant à :

- mesurer une période d'arrêt (figure 5 T0 à T1) d'un circuit de commande (34) d'un compresseur (4) dans le but de retarder l'application de courant au compresseur (4) ;
- détecter un appel (figure 5 T1) de compresseur (4) à partir d'un capteur de valeur d'énergie (28) ; et
- toujours empêcher le fonctionnement du compresseur (4) pendant un intervalle (figure 5 T1 à T2) qui est une valeur dérivée de la période d'arrêt mesurée (figure 5 T0 à T1) et non inférieure à un temps d'arrêt minimum (figure 7 T1 à T3).

2. Procédé selon la revendication 1, dans lequel le fonctionnement du compresseur (4) est empêché à moins et jusqu'à ce que la période d'arrêt (figure 7 T1 à T2) ne dépasse une valeur prédéterminée (figure 7 T1 à T3), laquelle valeur permet une égalisation de pression de compresseur (4) significative.

3. Procédé selon la revendication 1, comprenant en outre les étapes consistant à :

- stocker la période d'arrêt (figure 5 T0 à T1) mesurée en dernier dans une mémoire ;
- calculer un pourcentage de la période d'arrêt ;
- empêcher le fonctionnement du compresseur (4) pour un délai (figure 5 T1 à T2) égal au pourcentage ; et
- faire fonctionner le compresseur (4) à la suite (figure 5 T2 à T4) du délai (figure 5 T1 à T2).

4. Procédé selon la revendication 1, comprenant en outre les étapes consistant à :

- mesurer un cycle actif (figure 6 T1 à T15) du temps de fonctionnement du compresseur (4) ;
- arrêter l'opération du compresseur (4) une fois que le cycle actif s'est étendu pendant un intervalle de temps actif significatif (figure 6 T2 à T3) ; et
- l'étape d'interruption de fonctionnement du compresseur (4) est pour un temps inactif mesuré d'un intervalle de repos (figure 6 T3 à T4), lequel intervalle de repos est court mais suffisant pour permettre :
- l'égalisation du compresseur (4) ;
- le refroidissement du moteur du compresseur (4) ; et
- l'efficacité résultant de l'intervalle de repos (figure 6 T3 à T4), qui est bref, pendant lequel une température de l'espace est sensiblement maintenue par une inertie thermique d'objets et de fluides refroidis quelconques dans l'espace.

5. Procédé de régulation d'un système de refroidissement (2) selon la revendication 1, ledit procédé comprenant les étapes consistant à :

- surveiller une valeur provenant d'un capteur de valeur d'énergie (28) ;
- déterminer à partir de ladite valeur si la valeur nécessite un appel pour le fonctionnement du compresseur (4) ;
- générer un appel lorsque cela est nécessaire (figure 7 T2) ;
- mesurer une période d'arrêt avant ledit appel à partir d'une extinction (figure 7 T1-T2) précédente du compresseur (4) ;
- stocker la période d'arrêt (figure 7 T1 à T2) mesurée en dernier dans une mémoire ;
- dans lequel le temps inactif minimum (figure 7 T1 à T3) permettrait une égalisation de pression du compresseur (4) significative ;
- calculer un pourcentage de la période d'arrêt ;
- la valeur dérivée de la période d'arrêt mesurée (figure 5 T0 à T1) est égale au pourcentage ;
- faire fonctionner le compresseur (4) à la suite de l'intervalle ;
- mesurer un cycle actif (figure 6 T1 à T15) du temps de fonctionnement du compresseur (4) ;
- interrompre le fonctionnement du compresseur (4) une fois que le cycle actif s'est étendu pendant un intervalle significatif (figure 6 T2 à T3) suffisant pour amener un espace à une température d'équilibre ; et
- empêcher le fonctionnement du compresseur (4) pendant un intervalle de repos prédéterminé (figure 6 T3 à T4), lequel intervalle de repos est court mais suffisant pour permettre :
- une égalisation du compresseur (4),
- un refroidissement du moteur du compresseur (4), et
- une amélioration de l'efficacité en sauvegardant de l'énergie pendant l'intervalle de repos (figure 6 T3 à T4), pendant lequel intervalle de repos une inertie thermique d'objets et de fluides refroidis quelconques dans l'espace maintient sensiblement une température dans l'espace.

6. Procédé selon la revendication 5, dans lequel un ensemble suivant de valeurs optimales est sensiblement utilisé :

- le temps inactif minimum (figure 7 T1 à T3) est trois minutes ;
- le pourcentage est dix pourcents ;
- l'intervalle significatif (figure 6 T2 à T3) est 54 minutes ; et
- l'intervalle de repos prédéterminé (figure 6 T3 à T4) est 6 minutes.

7. Système de refroidissement (2) comprenant un compresseur (4), un milieu de refroidissement et un échangeur de chaleur, comprenant en outre ;

- un capteur de valeur d'énergie (28) ; et
- des moyens :
- pour surveiller le capteur de valeur d'énergie (28),
- pour contrôler le compresseur (4),
- pour déterminer la charge thermique sur le système de refroidissement (2),

- pour mesurer une période d'arrêt (figure 5 T0 à T1) d'un circuit de commande (34) de compresseur (4),
- pour recevoir un appel de compresseur (4) provenant du capteur de valeur d'énergie (28), et
- pour toujours empêcher le capteur de valeur d'énergie (28) de faire fonctionner le compresseur (4) du système pour un intervalle (figure 5 T1 à T2) qui est une valeur dérivée de la période d'arrêt mesurée.

8. Appareil selon la revendication 7, dans lequel le moyen de contrôle comprend :

- une coupure dans un fil de fourniture de courant (36 ou 39) entre :
- le capteur de valeur d'énergie (28), et
- le compresseur (4) ; et
- des moyens (34) pour former un pont de manière commutable sur ladite coupure.

9. Appareil selon la revendication 8 dans lequel le moyen destiné à surveiller le capteur de valeur d'énergie (28) comprend :

- un fil chaud (36 ou 39) activé par le capteur de valeur d'énergie (28) en réponse à une valeur d'énergie au niveau de laquelle l'espace nécessite plus de refroidissement ; et
- un moyen de commutation (104) destiné à être actionné par une tension sur le fil chaud (36 ou 39).

10. Appareil selon la revendication 9 dans lequel le moyen de commutation (104) destiné à être actionné par une tension sur le fil chaud (36 ou 39) est un circuit électronique (104) destiné à détecter une large plage d'entrées de tension.

11. Appareil selon la revendication 10 dans lequel la large plage d'entrées de tension est entre 24 VAC et 240 VAC.

12. Appareil selon la revendication 10 dans lequel le circuit électronique comprend un photocoupleur (104).

13. Appareil selon la revendication 10 dans lequel le circuit électronique comprend un microcontrôleur (60).

14. Appareil selon la revendication 13 avec des moyens destinés à augmenter un temps de fonctionnement par cycle du compresseur (4) et ainsi à améliorer une utilisation électrique et à diminuer un temps de fonctionnement total du compresseur (4).

15. Appareil selon la revendication 7 dans lequel le capteur de valeur d'énergie est un thermostat (28).

16. Appareil selon la revendication 7 dans lequel le capteur de valeur d'énergie est un pressostat (40).

17. Appareil selon la revendication 8 dans lequel le moyen de commutation (31) se trouve dans une position normalement fermée de telle sorte que, si la fourniture de courant (42) ou le contrôleur (34) ne fonctionne pas, le système de refroidissement (2) fonctionne toujours.

18. Procédé selon la revendication 1, dans lequel si la période d'arrêt (figure 5 T0 à T1) du compresseur (4) a été supérieure à une valeur maximale, l'intervalle est sensiblement zéro.

19. Procédé selon la revendication 18, dans lequel la valeur maximale est sensiblement une heure.

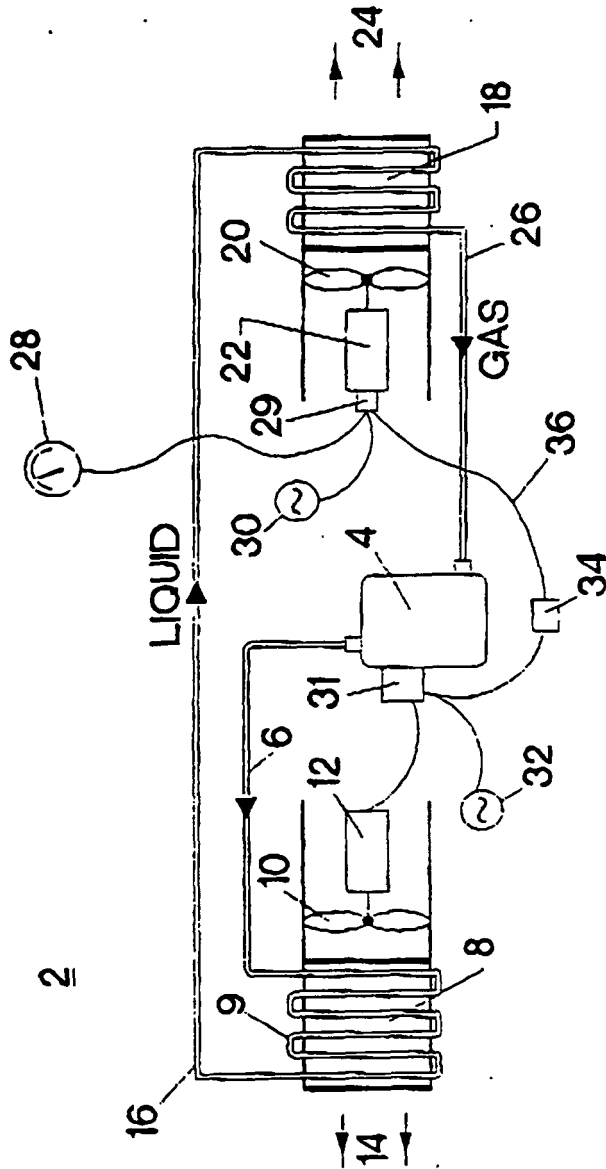


Fig. 1A

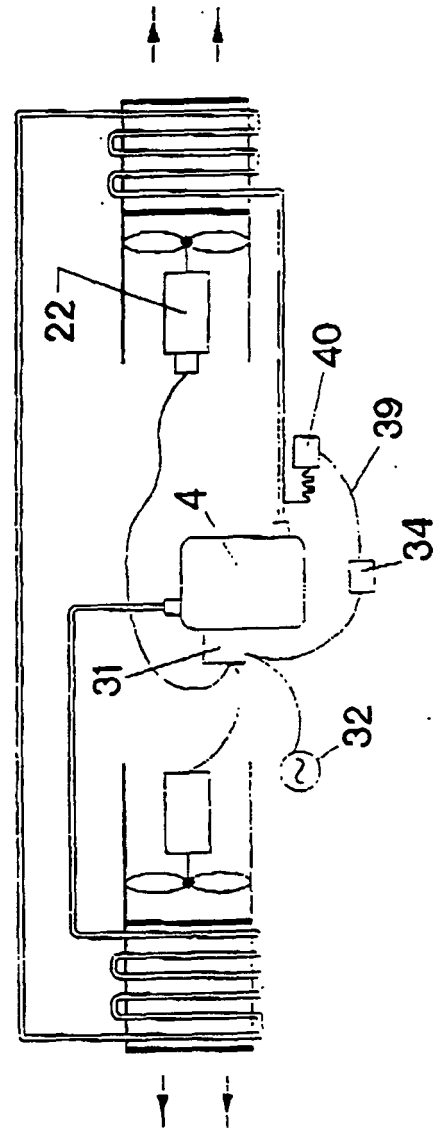


Fig. 1B

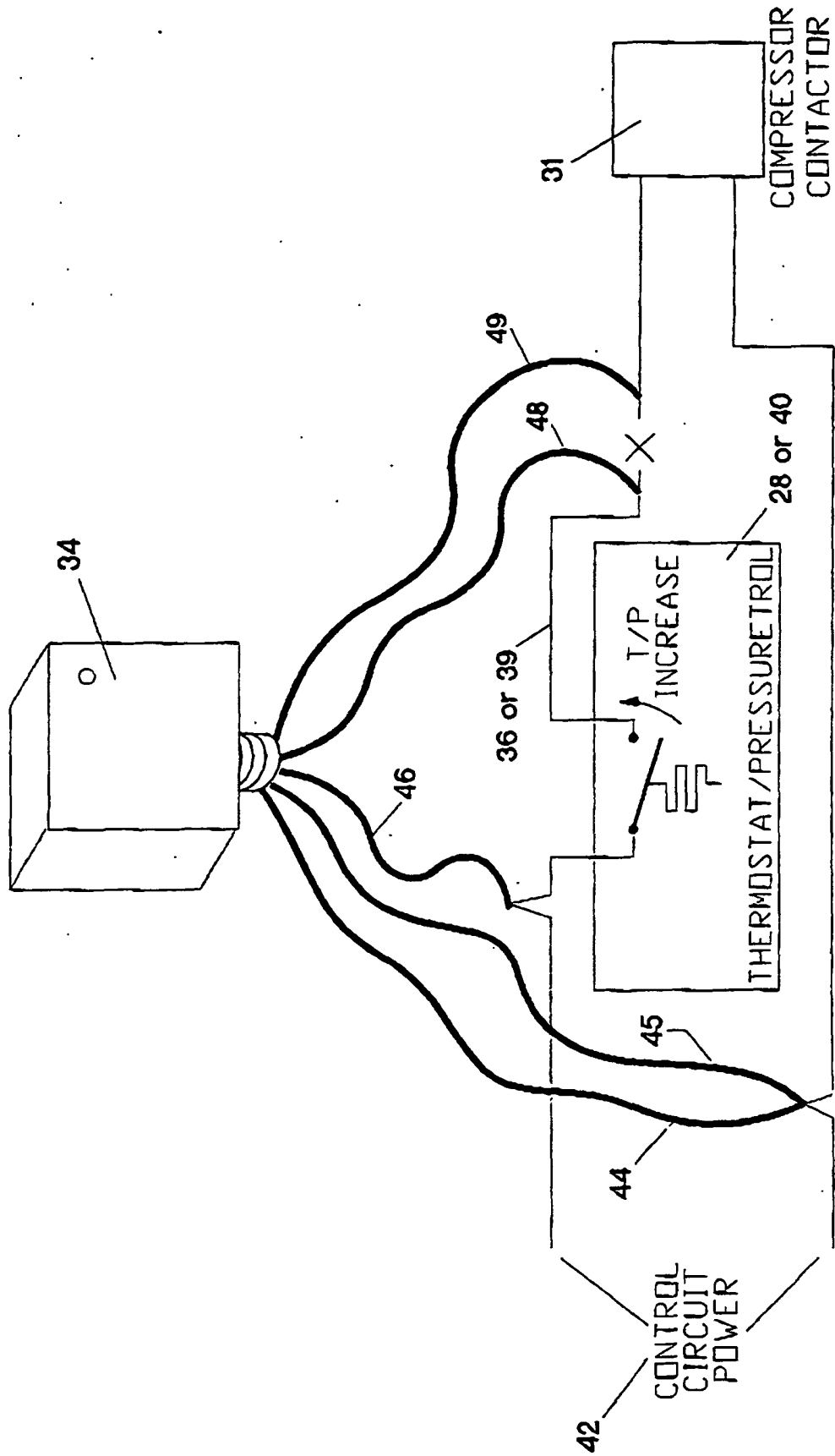


Fig. 2

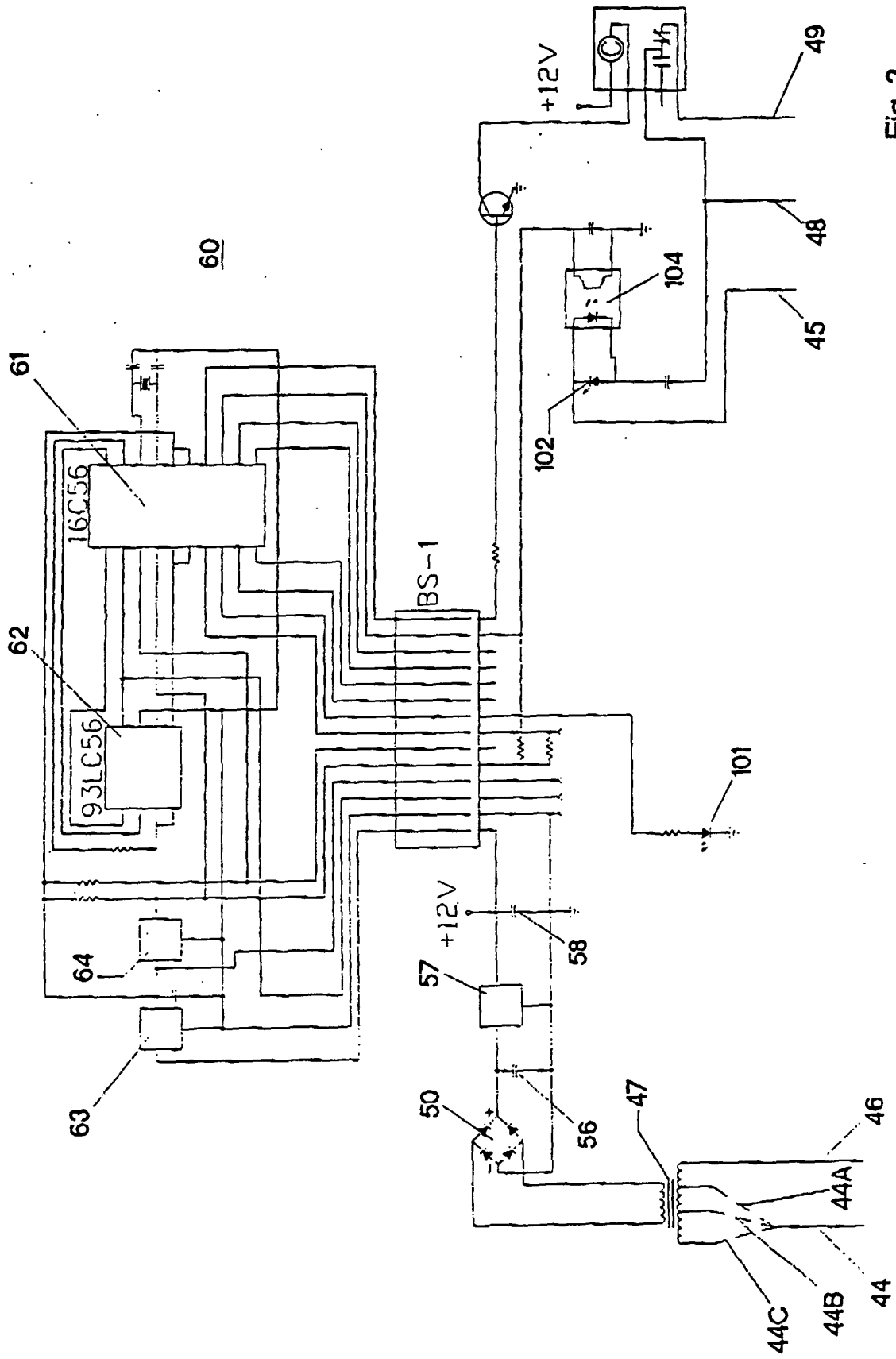


Fig. 3

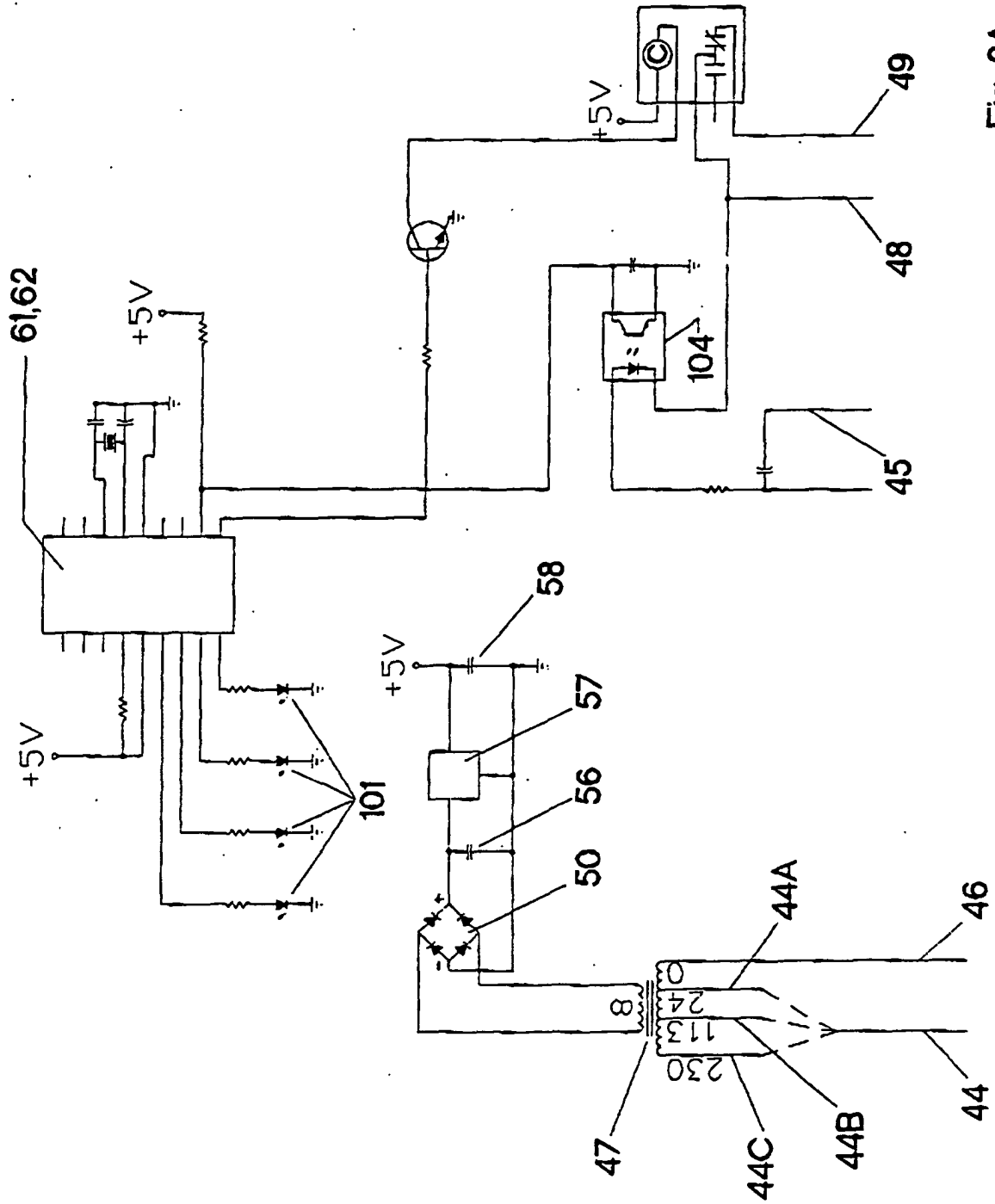


Fig. 3A

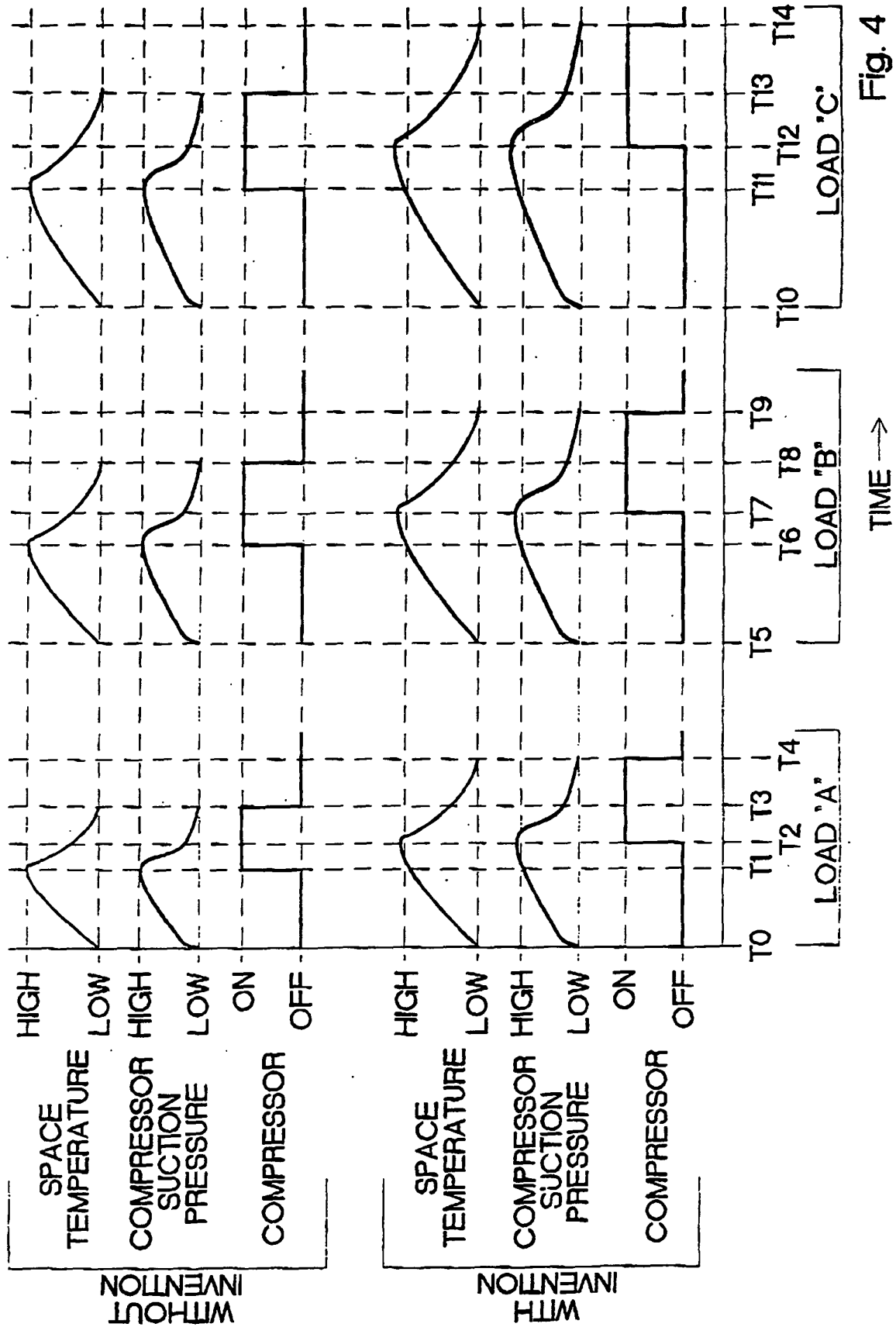


Fig. 4

TIME →

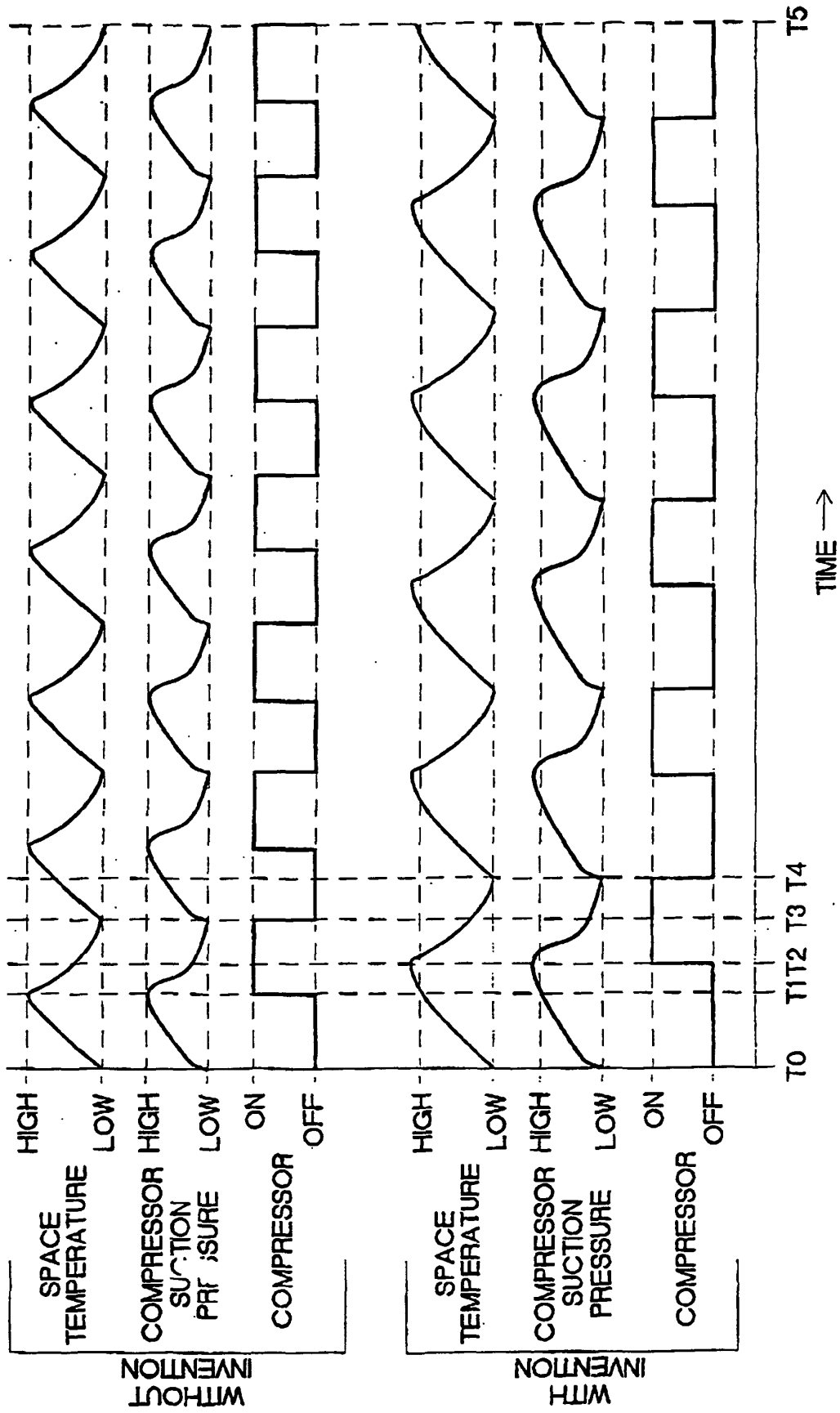


Fig. 5

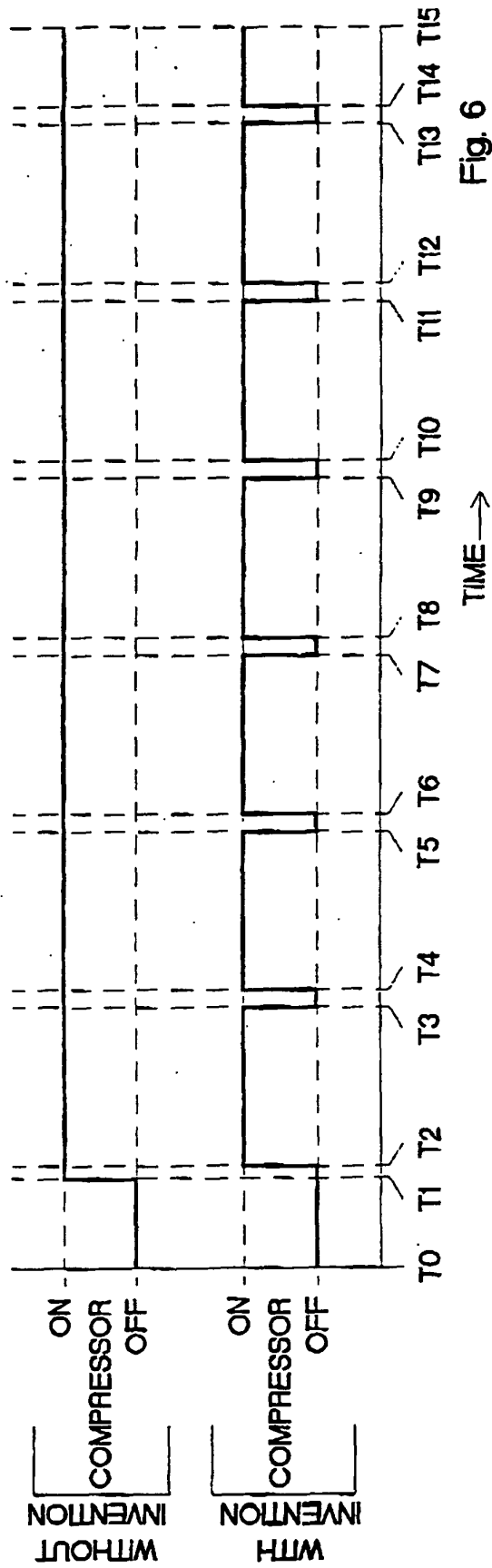


Fig. 6

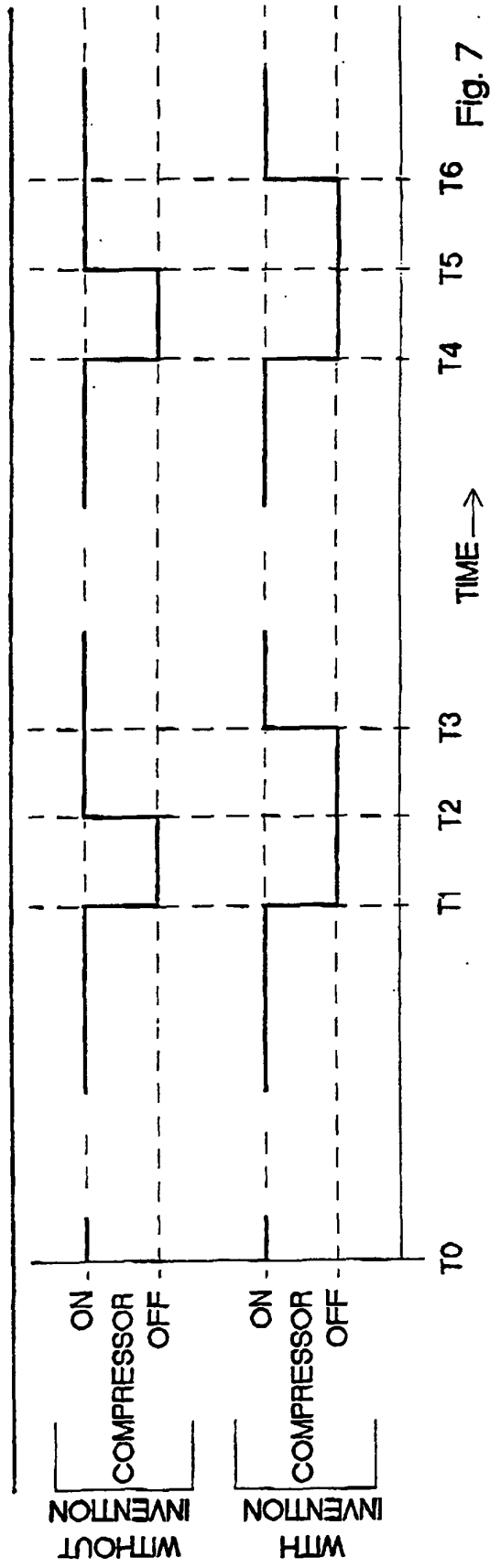


Fig. 7