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(54) Titre : METHODE ET APPAREIL DESTINES A INDUIRE L'HIBERNATION ARTIFICIELLE D'UN ANIMAL MARIN
(54) Title: METHOD AND APPARATUS FOR INDUCING ARTIFICIAL HIBERNATION OF MARINE ANIMAL

WATER TEMPERATURE (°C)	TIME (min)				TOTAL TIME CONSUMED
13	10				1185min (19h45m)
12		20			
11			30		
10				40	
9					
8					
7					
6					
5					
4					
3					
2					
1					
C.S.					

(57) Abrégé/Abstract:

A method for inducing artificial hibernation of fin fish in sea water contained in a container. The method involves monitoring the amount of mean oxygen consumption by the fin fish in the an water for a pre-determined period of time. The sea water temperature is gradually reduced on a step-wise basis in a first plurality of successive steps. In each step the sea water temperature is kept constant for a predetermined period of time and the predetermined period of time is increased with each successive step until a sea water temperature is reached wherein there is approximately no deviation of mean oxygen consumption by the fin fish. The sea water temperature may be further reduced on a step-wise basis for a second plurality of successive steps and the predetermined periods of time associated with each step of the second plurality may be reduced until artificial hibernation of the fin fish occurs.

Abstract

A method for inducing artificial hibernation of fin fish in sea water contained in a container. The method involves monitoring the amount of mean oxygen consumption by the fin fish in the sea water for a pre-determined period of time. The sea water temperature is gradually reduced on a step-wise basis in a first plurality of successive steps. In each step the sea water temperature is kept constant for a predetermined period of time and the predetermined period of time is increased with each successive step until a sea water temperature is reached wherein there is approximately no deviation of mean oxygen consumption by the fin fish. The sea water temperature may be further reduced on a step-wise basis for a second plurality of successive steps and the predetermined periods of time associated with each step of the second plurality may be reduced until artificial hibernation of the fin fish occurs.

METHOD AND APPARATUS FOR INDUCING ARTIFICIAL HIBERNATION OF MARINE ANIMAL

BACKGROUND

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Technical Field

The present invention relates to transportation and storage of marine animals and more particularly to methods and apparatus for inducing artificial hibernation of marine animals.

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RELATED ART

Rapid improvement of fish raising technologies (aquaculture) in the 1980s has prompted a significant increase of high value or quality fishery products from aquaculture farms in Korea starting from the early 1990s. For example, total mariculture fishery products in 1997 amounted to 39,121 tons. Demand and consumption of live fish (the word "fish" is used herein to include fin fish such as halibut, crustaceans such as crabs, and shellfish such as clams and other aquatic animals) has greatly increased partially due to increased personal income. However, current domestic circulation of aquatic fisheries products including live fishery products depends on low density (approximately 15-20% of total weight) transportation systems using trucks equipped with water-filled tanks. This results in many associated distributional problems including difficulty in maintaining freshness due to delay in delivery caused by transportation problems such as traffic congestion; high transportation cost due to high fuel/labor costs and distance from farm and final consumers; and spoiled taste when the live fish is hauled long distances over land.

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Typical methods for transporting such marine animals including live fish can be broadly categorized into four types, that is, (1) anesthetic transport, (2) electric shock transport, (3) cooling tank transport, and (4) artificial (dormant state of) hibernation transport.

An exemplary system and method for transporting the live fish is described in Korean Patent Registration No. **10-0232408** entitled "High Density Transport Method of Live Fish using Cooled Water", in which water, ice and salt are placed into a live fish water tank, and the temperature of water therein is cooled by **5 ~ 15** degrees Celsius lower than the typical transport water temperature.

Other systems and methods are disclosed, for example, in Korea Patent Registration No. **10-0531728** entitled "Icy Sea Water Cooling Apparatus for Live Cuttlefish Transport and Storage" an icy seawater cooling apparatus is proposed for storage and transportation of cuttlefish in a low temperature state. Korea Patent Registration No. **10-0046109** entitled "Method and Apparatus for Storage and Transportation of Live Fish" provides a tank with several holes that is maintained at a low temperature for accommodating in each hole one or more fish to protect live fish from being bodily injured and for restraining the fish from moving freely.

However, as all these disclosures basically require a method for lowering the temperature of a water tank containing live fish, there are still problems with live fish tank transportation methods using truck delivery systems for domestic and foreign consumption (hereinafter referred to as "tank transport"). Specialized equipment for live fish tank transportation is costly, and there are uncertainties of the effect of the low temperature environment on various kinds of fish. In addition, high mortality of live fish persists during long haul transportation over land. The anesthetic transport method may cause hygienic safety problems and abhorrence. The electric shock transport method may also pose a difficulty in pre-treatment, high morality rate, and deteriorated flesh quality of live fish.

SUMMARY OF THE INVENTION

In accordance with one aspect of the invention, the temperature of sea water containing marine animals is lowered in a stepwise process, while the sea water temperature at each step is maintained for a predetermined period of time. The predetermined period maintained for each step is gradually increased to a point such that changes in oxygen consumption (oxygen

requirement) by the marine animals are greatly decreased or reduced to almost nothing. Then, starting from this point, the period for constantly maintaining the desired temperature of sea water at each step is gradually reduced, thereby ensuring a long survival rate (viability) of marine animals.

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In accordance with another aspect of the invention, there is provided a method for inducing artificial hibernation of fin fish in sea water contained in a container. The method involves monitoring the amount of mean oxygen consumption by the fin fish in the sea water for a first pre-determined period of time. The method also involves gradually reducing the sea water temperature on a step-wise basis in a first plurality of successive steps. In each step the sea water temperature is kept constant for a respective predetermined period of time and the respective predetermined period of time is increased with each successive step until a sea water temperature is reached wherein mean oxygen consumption by the fin fish is approximately constant. The method further involves then continuing to gradually reduce the sea water temperature on a further step-wise basis for a second plurality of successive steps and gradually reducing the respective predetermined periods of time associated with each step of the second plurality until artificial hibernation of the fin fish occurs.

In accordance with another aspect of the invention, there is provided a method for inducing artificial hibernation of fin fish in sea water contained in a container. The method involves monitoring the amount of mean oxygen consumption by the fin fish in the sea water for a first pre-determined period of time to determine an initial oxygen consumption value. The method also involves gradually reducing the sea water temperature on a step-wise basis in a first plurality of successive steps until the respiratory rate or endogenous biorhythm in the fin fish indicates the fin fish is most stressed. In each step the sea water temperature is kept constant during each respective predetermined period of time and the respective predetermined period of time is increased with each successive step. The method further involves continuing to gradually reduce the sea water temperature on a further step-wise basis for a second plurality of successive steps wherein the respective predetermined period of time that is maintained during each step-wise reduction of sea water temperature is reduced, starting from a step in which the sea water

temperature is such that a difference between a maximum and a minimum oxygen consumed by the fin fish is **1.5 to 4** times smaller than the initial oxygen consumption value or such that a deviation of oxygen consumption by the fin fish is in the range of **6.0ml O₂ kg⁻¹ WW h⁻¹ ~ 0.0ml O₂ kg⁻¹ WW h⁻¹**.

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In accordance with another aspect of the invention, there is provided a method for inducing artificial hibernation of fin fish kept in sea water in a container. The method involves determining an initial oxygen consumption of the fish at an initial temperature, for a first period of time. The method also involves gradually lowering the water temperature to a second
10 temperature for a second period of time, where the second temperature is a temperature at which the oxygen consumption is **3 to 4** times lower than the initial oxygen consumption, and the second period of time is **10 to 100** times longer than the first period of time.

In accordance with another aspect of the invention, there is provided a method for inducing
15 artificial hibernation of fin fish in sea water contained in a container. The method involves monitoring the amount of mean oxygen consumption by the fin fish for a first predetermined period of time while holding the sea water temperature at a first pre-determined temperature. The method also involves gradually reducing the sea water temperature to a second predetermined temperature for a second predetermined period of time that is **10 to 25** times
20 longer than the first predetermined period of time. The mean oxygen consumption during the second predetermined period of time is **1.5 to 2.5** times lower than the amount of mean oxygen consumption during the first predetermined period of time. The method further involves then continuing to gradually reduce the sea water temperature to a third predetermined temperature, for a third predetermined period of time that is **26 to 100** times longer than the first
25 predetermined period of time. The mean oxygen consumption is **3 to 4** times lower than the mean oxygen consumption during the first predetermined period of time.

In accordance with another aspect of the invention, there is provided a method for inducing
artificial hibernation of fin fish kept in sea water in a container. The method involves
30 maintaining the sea water at a first temperature for a first period of time and lowering the sea

water temperature to a second temperature at which a difference between the maximum and minimum oxygen consumption by the fin fish is in the range of $6.0\text{ml O}_2 \text{ kg}^{-1} \text{ WW h}^{-1} \sim 1.0\text{ml O}_2 \text{ kg}^{-1} \text{ WW h}^{-1}$. The method also involves keeping the sea water at the second temperature for a second period of time which is **10** to **25** times longer than the first period of time and gradually lowering the water temperature to a third temperature where a difference between the maximum and minimum oxygen consumption by the fin fish is in the range of $1.1\text{ml O}_2 \text{ kg}^{-1} \text{ WW h}^{-1} \sim 0.0\text{ml O}_2 \text{ kg}^{-1} \text{ WW h}^{-1}$. The method further involves keeping the sea water at the third temperature for a third period of time which is **26** to **100** times longer than the first period of time.

The first temperature may be in the range of **14** ~ **12** degree Celsius, the second temperature may be in the range of **7** ~ **5** degree Celsius, and the third temperature may be in the range of **5** ~ **3** degrees Celsius.

In accordance with another aspect of the invention, there is provided a method for inducing artificial hibernation of fin fish kept in sea water in a container. The method involves maintaining the sea water at a first temperature for a first period of time and gradually lowering the water temperature to a second temperature where a difference between the maximum and minimum oxygen consumption by the fin fish is in the range of $1.1\text{ml O}_2 \text{ kg}^{-1} \text{ WW h}^{-1} \sim 0.0\text{ml O}_2 \text{ kg}^{-1} \text{ WW h}^{-1}$. The method also involves keeping the sea water at the second temperature for a second period of time that is **10** to **100** times longer than the first period of time.

Gradually lowering the sea water temperature may involve gradually decreasing the sea water temperature in steps, wherein successive steps may have respective successively increasing time periods.

The initial temperature may be **13** degrees Celsius, and the second temperature may be **4** degrees Celsius.

In accordance with another aspect of the invention, there is provided a method for transporting fin fish. The method involves inducing an artificial hibernation state of the fin fish by maintaining the fin fish in sea water for a predetermined period of time, gradually decreasing the sea water temperature according to predetermined temperature steps in a stepwise process while gradually increasing the time of maintaining the sea water temperature constant at each predetermined temperature step until the seawater has reached a first pre-defined temperature, then continuing to gradually decrease the seawater temperature in predetermined steps while gradually decreasing the time of maintaining the sea water temperature constant at each predetermined temperature step until the seawater has reached a second pre-defined temperature such that said fin fish enter said hibernated state. The method further involves transporting fin fish in the hibernated state.

The sea water temperature may be gradually lowered by approximately 1, 2, or 3 degree(s) Celsius per predetermined temperature section.

The predetermined periods of time at each predetermined temperature section may be approximately 10, 20, 30, 40, 50, 60, 80, 120, 180, 260, 180, 120, 20 and 15 minutes, respectively.

The fin fish may be live halibut or other live fish.

In accordance with another aspect of the invention, there is provided an apparatus for inducing artificial hibernation of fin fish. The apparatus includes an artificial dormant chamber for containing sea water including the fin fish and a heat exchanger or a cooler for gradually lowering the temperature of the sea water discharged from the artificial dormant chamber according to a predetermined schedule and introducing the lower temperature sea water back into the artificial dormant chamber. The apparatus also includes temperature sensing means for sensing the temperature of sea water contained in the artificial dormant chamber, an oxygen sensor for measuring the level of dissolved oxygen contained in the sea water, and a controller for controlling the heat exchanger or cooler. The apparatus further includes a computer readable

medium encoded with codes for directing the controller to control the heat exchanger or cooler to gradually reduce the sea water temperature on a step-wise basis in a first plurality of subsequent steps in accordance with the amount of oxygen consumed by the fin fish during each subsequent step. In each step the sea water temperature is kept constant for a predetermined period of time.

5 The predetermined period of time is increased with each successive step. The temperature is reduced until a sea water temperature is reached wherein mean oxygen consumption by the fin fish is approximately constant.

10 The artificial dormant chamber may include a fishing net capable of harvesting the fin fish from the sea water.

15 In one embodiment, marine animals are left to swim in sea water for a predetermined period of time. In other words, the sea water including the marine animals is prepared as a first step. "Sea water" denotes water from the ocean, but fresh water and other water may be used in the present invention, apart from the sea water. Although exemplary embodiments of the present invention have described sea water for the sake of convenience, it should be apparent that fresh water and other types of water may be used apart from sea water.

20 Next, the temperature of the sea water thus prepared is gradually lowered in steps, and the period of maintaining the sea water temperature at each step is gradually increased. In other words, the temperature of prepared sea water is gradually lowered but the sea water temperature at each step is maintained for a predetermined period, which is gradually increased with each step.

25 It is known that marine animals can be kept in good condition for a longer time if they are kept in water that is significantly cooler than water normal for their usual habitat or in ice. In the present invention the water temperature is lowered at intervals to induce dormancy.

30 In one embodiment, if the prepared sea water is 13 degrees Celsius, and marine animals are left to stay therein for 10 minutes, the sea water temperature is gradually lowered at each step 1 degree Celsius, and the duration of each step is gradually increased to 20 minutes, 30 minutes, 40

minutes and 50 minutes at 12 degrees Celsius, 11 degrees Celsius, 10 degrees Celsius and 9 degrees Celsius (hereinafter all the temperatures are based on Celsius), respectively

Effectively a long survival rate of marine animals may be achieved by artificially inducing dormancy in the marine animals. The artificially dormant-induced marine animals can then be

packed in a box in a waterless condition. Artificially inducing dormancy to facilitate a waterless condition for the living marine animals may be achieved by stopping the endogenous biorhythm for a long time by allowing the external environment of the living marine animals to go through various temperature changes in response to the biorhythms of the living marine animals. After long transportation the biorhythms of the artificially induced hibernating marine animals may be recovered.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG.1 is a mimetic diagram explaining a first exemplary embodiment of the present invention where the periods during which the marine animals are kept at predetermined temperatures are gradually increased and then gradually decreased as the sea water temperature is gradually lowered.

FIG.2 is a mimetic diagram explaining a second exemplary embodiment of the present invention where the periods during which the marine animals are kept at predetermine temperatures are gradually increased and then gradually decreased as the sea water temperature is gradually lowered.

FIG.3 is a block diagram illustrating an automatic respiration measurement instrument for measuring oxygen requirements of marine animals, according to one embodiment of the invention.

FIGS.4 and 5 each show an exemplary graph illustrating a respiratory state of cultured marine animals measured according to the present invention and a cyclic rhythm obtained from the respiratory state.

FIGS.6 and 7 each show an exemplary graph illustrating a respiratory state of cultured marine animals measured according to the present invention and circadian or circadian rhythms obtained from the respiratory state.

FIG.8 is an exemplary graph illustrating changes in oxygen consumption of marine animals in response to sea water temperature for determining a sea water temperature of at which changes in oxygen consumption of the marine animals are greatly reduced or negligible.

FIG.9 is an exemplary graph illustrating a relation between sea water temperature and time depicting gradually increasing periods of time during which organisms are maintained at a predetermined temperature in response to the gradually decreased sea water temperature.

FIGS. 10 and 11 show a side view and a top view respectively of an artificial hibernation apparatus according to an embodiment of the present invention.

DETAILED DESCRIPTION

It was confirmed from the embodiments of the present invention that aquatic animals can be most effectively induced to a dormant state of hibernation by gradually reducing sea water temperature at a predetermined interval and gradually increasing the period during which animals are maintained at a predetermined temperature at each decreased temperature. If the sea water temperature is temporarily lowered to an ultimately desired temperature in one step, the aquatic animals can die due to severe stress on their physiological processes caused by significantly reduced temperature. In the present invention, water temperature and duration are gradually adjusted in a stepwise manner to allow the aquatic animals to adapt to the reduced temperature at each step until an ultimately desired temperature is reached.

Referring to FIG.1, in one embodiment the sea water temperature is gradually lowered in 1 degree Celsius steps, each step having a respective time period. It will be appreciated however that the sea water temperature may alternatively be gradually lowered by 2, 3 or more degrees Celsius, where the duration of time at each temperature may vary. Where the temperature is lowered in 1 degree Celsius steps, for example, the prepared sea water may be maintained at 13 degrees Celsius, and an aquatic animal may be kept therein for 10 minutes, then the sea water may be maintained at 11 degrees Celsius for 20 minutes, and then the sea water may be maintained at 9 degrees Celsius for 30 minutes. Although the gradual decrease of temperature of the sea water occurs in discrete stepwise fashion, it will be appreciated that it takes time to lower the sea water temperature between steps and thus, the stepwise reduction in temperature may be illustrated as overlapping steps as shown in FIG.2.

The time periods of successive steps of decreased temperature are increased until the animals are most stressed. The sea water temperature at which the aquatic animals are most stressed is determined from the respiratory state or endogenous biorhythm of the aquatic animals. Once the step at which the animals are most stressed is reached, the period during which the animals are maintained at predetermined constant temperature of sea water for each step is gradually decreased, i.e. the period of the steps is decreased. Thus, decreases in the periods of each step are initiated when changes in the oxygen requirements of the animals are greatly reduced, or remain almost unchanged.

When the sea water temperature is reduced, the aquatic animals in the sea water experience difficulties in breathing and their respiration becomes irregular, and changes in the oxygen requirements of the aquatic animals are greatly reduced or are almost zero at a predetermined temperature. At this temperature, the respiratory biorhythm of the aquatic animals is significantly reduced or has ceased. The aquatic animals are most stressed at this temperature. In the present invention, the period during which the temperature of the sea water is held constant the longest is a sea water temperature at which the changes in the oxygen requirements of the aquatic animals are greatly reduced, or are negligible. Subsequently, the periods of steps of

successively lower temperature are gradually reduced, thereby minimizing the stress on the aquatic animals and artificially inducing them into a dormant state of hibernation.

5 The term "changes of the oxygen requirements consumed by the aquatic animals are greatly reduced, or are negligible" denotes that i.e., deviation (i.e., amplitude) between maximum oxygen consumption and minimum oxygen consumption is greatly reduced, or nominal. The term "amplitude of oxygen consumption by the aquatic animals analyzed at a predetermined temperature is nominal" refers to a state where
10 the respiratory activities of the aquatic animals are diminished by the stress of being at the pre-determined temperature. The term "amplitude of oxygen consumption by the aquatic animals analyzed at a predetermined temperature is great" refers to a state where the respiratory activities are vigorous. The determination of whether the animals exhibit diminished or vigorous respiratory activities is made by measuring
15 changes in oxygen dissolved in the sea water in which the animals reside.

One embodiment described herein involves keeping a marine animal of an initial oxygen consumption in sea water of a predetermined temperature for a predetermined period of time and gradually lowering the sea water temperature in steps having
20 increasing duration. In one embodiment the predetermined duration of time that the subjected marine animals are kept at each step-down temperature are then reduced, starting from a sea water temperature where the oxygen consumed by the marine animals is 1.5 to 4 times smaller than the initial oxygen consumption or where a deviation of oxygen consumption by the marine animals is in the range of 6.0ml O₂
25 kg⁻¹ WW h⁻¹ ~ 0.0ml O₂ kg⁻¹ WW h⁻¹.

In order to check for a deviation of oxygen consumption by the aquatic animals at a predetermined temperature, a respiratory state of the aquatic animals is determined prior to reducing the sea water temperature. Therefore, a method according to one
30 aspect of the invention may begin with measuring the respiratory state of the aquatic animals. This is done by determining the oxygen consumption of the aquatic animals by measuring the dissolved oxygen in the sea water containing the aquatic animals.

An automatic respiration measuring apparatus may be employed for measuring the respiratory state of the aquatic animals.

5 An exemplary automatic respiration measuring apparatus is described in Korea laid-open Patent No. 10- 2003-0075931. A basic form of this apparatus is shown in FIG.3, and automatically corrects a dissolved oxygen concentration measurement for atmospheric pressure, to measure the respiratory state of aquatic animals. The apparatus includes a main closed-circulation loop in which water is circulated, an aquatic animal storage tank arranged to communicate with the main closed-circulation loop for storing and maintaining the aquatic animals, a parallel-connected auxiliary circulation loop with the main closed-circulation loop for supplying the supplementary water saturated and dissolved with oxygen to the main closed-circulation loop, and a computing control system for communicating with the auxiliary circulation loop and the main closed-circulation loop for measuring the dissolved oxygen in the main closed-circulation loop. A detailed explanation of the operation of this apparatus is provided in Korea laid-open Patent No. 10-2003-0075931.

20 The endogenous biorhythm of the aquatic animals may be analyzed from the result of the respiratory state of the aquatic animals measured as described above. Preferably, measurements of dissolved oxygen concentration for analyzing the endogenous biorhythm of the aquatic animals are obtained in experimental conditions of "no light", known sea water temperature and known salinity. Desirably, mean oxygen consumption at predetermined periods of time is obtained to analyze the endogenous biorhythm of the aquatic animals. Changes in atmospheric pressure, water temperature and salinity that have an influence on the oxygen dissolved in the water may be taken into account to automatically correct dissolved oxygen concentrate measurements, if necessary. The results of respiratory state determination may be used to determine whether metabolic activities of the aquatic animals have a cyclic rhythm or a circatidal rhythm. For example, FIG.4 shows an exemplary graph illustrating biological respiratory activities of cultured halibut measured consecutively for 6 days using the automatic respiration measuring apparatus. From the graph shown in FIG.4, a metabolic activity cycle of the aquatic animal can be determined

using time series analysis. Based on such analysis, a robust cyclic rhythm can be obtained, as shown in FIG.5.

5 For comparison, FIG.6 shows continuous biological respiratory activities measured from halibut captured in the natural habitat, and FIG.7 is an analysis of continuous biological respiratory activities measured by the cycle analysis program. FIG.7 shows that circatidal rhythms formed in the natural habitat exist within the body of the aquatic animal.

10 The analysis of endogenous biorhythms of aquatic animals resulting from the respiratory state of the aquatic animals may be obtained using a predetermined computer system or a program, or may be obtained using other methods widely known in the related field,

15 In the embodiment described a sea water temperature at which the aquatic animals are most stressed is identified from the respiratory state or endogenous biorhythm of the aquatic animals, and the period during which the animals are maintained at a predetermined constant temperature of sea water in each successive step of lowering the sea water temperature is lengthened such that the longest period occurs when the
20 animals are most stressed. The determination of stress described herein may be equally applied to aquatic animals having cyclic rhythms or circatidal rhythms, or having both cyclic and circatidal rhythms.

FIG.8 is an exemplary graph illustrating changes in oxygen consumption of marine
25 animals in response to sea water temperature for determining a sea water temperature of a point where the changes of oxygen consumption of the aquatic animals is greatly reduced or remains almost unchanged i.e. for determining when the animals are stressed. More particularly, FIG.8 is an exemplary graph illustrating changes of mean oxygen consumption of halibut, which have a 24-hour cyclic rhythm, in response to
30 the sea water temperature.

Referring to FIG.8, mean oxygen consumption decreases as the sea water temperature decreases, and the deviation of oxygen consumption by the aquatic animals at a

predetermined temperature, i.e., a difference between maximum oxygen consumption and minimum oxygen consumption by the aquatic animals at a given temperature also decreases as the sea water temperature is reduced. Thus aquatic animals become less active at the reduced sea water temperature, and as a result, the changes in oxygen consumption decrease or reach a zero state.

When the changes in oxygen consumption decrease sufficiently or reach a zero state, there is a change in the endogenous biorhythms of the aquatic animals. For example, as shown in FIG.8, the sea water temperatures at which the endogenous biorhythms are changed may occur, where the sea water started at 13 degree Celsius, at about 10 degree Celsius. At about this temperature, the respiratory metabolic activities of a halibut weakens from a normal state (point A). At about 6 degrees Celsius (point B) the respiratory endogenous biorhythms are greatly reduced in response to the decreased water temperature. At about 4 degrees Celsius the respiratory endogenous biorhythms cease (point C), and at about 2 degrees Celsius there is no change of metabolic activities regardless of the further decreased water temperature (point D).

In one embodiment the sea water temperature may be reduced in three steps. In a first step a first temperature associated therewith may encompass a range of 14 to 12 degrees Celsius, in a second step a second temperature associated therewith may encompass a range of 7 to 5 degrees Celsius, and in a third step a third temperature associated therewith may encompass 3 degrees Celsius. Preferably, the first temperature is 13 degrees Celsius, the second temperature is 6 degrees Celsius and the third temperature is 4 degrees Celsius. Alternatively, the sea water temperature may be reduced from the first temperature to the third temperature skipping the step associated with the second temperature. In this embodiment, a marine animal having an initial oxygen consumption rate is kept for a first period in sea water at the first temperature, and successively, the temperature is gradually lowered and then the marine animal is maintained in sea water at the third temperature for the third period. In this embodiment, the third temperature is a temperature at which oxygen consumption by the marine animal is three to four times smaller than the initial oxygen consumption, and the third period has a duration of 10 to 100 times longer than the initial period.

The above description can be further explained with reference to Table 1 on p. 25 and FIG.1. A marine animal having an initial measured oxygen consumption of $12.2 \text{ ml O}_2 \text{ kg}^{-1} \text{ WW h}^{-1}$ is kept for 10 minutes at 13 degrees Celsius. Then, the water temperature is gradually lowered until the oxygen consumption is at least 3-4 times lower than the initial oxygen consumption and in this embodiment is $0.1 \text{ ml O}_2 \text{ kg}^{-1} \text{ WW h}^{-1}$ which occurs at 4-degrees Celsius. This temperature is maintained for approximately 260 minutes. At 4 degrees Celsius, respiratory endogenous biorhythm stops. If the marine animal is kept at 4 degrees Celsius for a period of time about 10 to 100 times longer than the first period of time (10 minutes), the marine animal may be least stressed as the marine animal is maintained therein for the longest period of time, although the third temperature phase is where the marine animal is the most stressed with almost no change of oxygen consumption.

In another embodiment of the present invention, the aquatic animal may have a first oxygen consumption at a first temperature of sea water which may be maintained for the first period. The water temperature may then be gradually lowered, and then maintained for a second period at a second temperature at which the animal exhibits a second oxygen consumption which is 1.5 to 2.5 times lower than the first oxygen consumption. The second period may be 10 to 25 times longer than the first period. Thereafter, the water temperature may be gradually lowered and then the water temperature may be maintained for a third period at a third temperature at which the animal exhibits a third oxygen consumption which is 3 to 4 times lower than the first oxygen consumption. The third period may be 26 to 100 times longer than the first period.

Now, referring to Table 1 and FIG.1, an aquatic animal having a first oxygen consumption of $12.2 \text{ ml O}_2 \text{ kg}^{-1} \text{ WW h}^{-1}$ is maintained for 10 minutes at 13 degree Celsius sea water, then at 6 degree Celsius for 120 minutes where the average oxygen consumption reached $9.8 \text{ ml O}_2 \text{ kg}^{-1} \text{ WW h}^{-1}$, and the respiratory endogenous biorhythms markedly changed, and then, at 4 degree Celsius for approximately 260 minutes where the average oxygen consumption of the aquatic animal reached $6.2 \text{ ml O}_2 \text{ kg}^{-1} \text{ WW h}^{-1}$. At this level of oxygen consumption, the respiratory endogenous biorhythms of the animal are considered to have ceased since the amplitude difference

in average oxygen consumption is only $0.1 \text{ ml O}_2 \text{ kg}^{-1} \text{ WW h}^{-1}$. In this embodiment, the second temperature (6 degrees Celsius) is where the change in oxygen consumption is greatly decreased and is therefore maintained for a predetermined period of time before initiating the third temperature to thereby ensure a long survival rate (viability) of aquatic animals.

In another embodiment of the present invention, the aquatic animal may be kept in sea water at the first temperature for the first period and then the water temperature may be gradually lowered to the third temperature at which the difference between the maximum and minimum oxygen consumption by the aquatic animal is minimized, e.g. an oxygen consumption biorhythm amplitude of $1.1 \text{ ml O}_2 \text{ kg}^{-1} \text{ WW h}^{-1} \sim 0.0 \text{ ml O}_2 \text{ kg}^{-1} \text{ WW h}^{-1}$. The aquatic animal is then maintained at the third temperature for a period 10 to 100 times longer than the first period.

Referring again to Table 1 and FIG.1, the third temperature, where the difference between the maximum and minimum oxygen consumption by the aquatic animal is in the range of $1.1 \text{ ml O}_2 \text{ kg}^{-1} \text{ WW h}^{-1} \sim 0.0 \text{ ml O}_2 \text{ kg}^{-1} \text{ WW h}^{-1}$ is with the range of $4.5 \sim 1$ degree Celsius. At the third temperature the aquatic animal is most stressed as seen by almost no change of oxygen consumption, but the third temperature may be maintained for a long period of time thereby giving the least stress to the aquatic animal according to the present invention.

Still another embodiment of the present invention may include keeping the aquatic animal in sea water at the first temperature for the first period, after which the water temperature is gradually lowered to the third temperature at which the difference between the maximum and minimum oxygen consumption by the aquatic animal, i.e., an oxygen consumption biorhythm amplitude of $1.1 \text{ ml O}_2 \text{ kg}^{-1} \text{ WW h}^{-1} \sim 0.0 \text{ ml O}_2 \text{ kg}^{-1} \text{ WW h}^{-1}$ is achieved. The aquatic animal is then maintained at the third temperature for a duration 10 to 100 times longer than the first period.

Referring again to Table 1 and FIG.1, the third temperature at which the difference between the maximum and minimum oxygen consumption by the aquatic animal, i.e., an oxygen consumption biorhythm amplitude of $1.1 \text{ ml O}_2 \text{ kg}^{-1} \text{ WW h}^{-1} \sim 0.0 \text{ ml O}_2 \text{ kg}^{-1}$

¹ WW h⁻¹, is approximately in the range of 4.5 to 1 degree Celsius, is where the aquatic animal may be most stressed as seen by near unchanged oxygen consumption, but as the aquatic animal is maintained therein for the longest period of time, the aquatic animal may be least stressed.

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Still another embodiment of the present invention may include maintaining the aquatic animal in sea water at the first temperature for the first period, and then gradually lowering the water temperature to the second temperature, at which the difference between the maximum and minimum oxygen consumption by the aquatic animal, is about 6.01 ml O₂ kg⁻¹ WW h⁻¹ ~ 1.0ml O₂ kg⁻¹ WW h⁻¹, and keeping the aquatic animal at the second temperature 10 to 25 times longer than the first period. Then the water temperature is gradually lowered to the third temperature at which the difference between the maximum and minimum oxygen consumption by the aquatic animal is about 1.1ml O₂ kg⁻¹ WW h⁻¹ ~ 0.0ml O₂ kg⁻¹ WW h⁻¹. The aquatic animal is then maintained at the third temperature 10 to 100 times longer than the first period.

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Referring again to Table 1 and FIG.1, the second temperature at which the difference between the maximum and minimum oxygen consumption by the aquatic animal is about 6.0ml O₂ kg⁻¹ WW h⁻¹ ~ 1.0ml O₂ kg⁻¹ WW h⁻¹ is approximately in the range of 7.0 to 4.5 degrees Celsius, and in this case, the second temperature is where the changed oxygen consumption is greatly reduced. The sea water is kept at this second temperature for a predetermined period of time prior to reducing the temperature to the third temperature to thereby ensure a long survival rate (viability) of aquatic animals.

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The gradual decrease of the water temperature in the aforementioned embodiments of the present invention is desirable to gradually reduce the water temperature between the important temperatures mentioned and to successively increase the time each reduced temperature is maintained. This is particularly so for a live fish or a halibut.

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FIGS. 10 and 11 show a side view and an upper surface view respectively of an exemplary artificial hibernation apparatus for artificially inducing marine animals into

a dormant state of hibernation according to another embodiment of the present invention.

Referring to FIGS. 10 and 11, the apparatus comprises: an artificial dormant chamber (15) containing sea water including aquatic animals; a heat exchanger (2) or a cooler (5) for gradually lowering temperature of the sea water discharged from the artificial dormant chamber (15) according to a predetermined schedule and introducing the lowered temperature of sea water back into the artificial dormant chamber (15); temperature sensors (11, 12) for measuring the temperature of sea water contained in the artificial dormant chamber (15); an oxygen sensor (10) for measuring the level of dissolved oxygen contained in the sea water; and a controller which may be a personal computer (PC. 9) for example, for controlling the heat exchanger or the cooler according to an artificial hibernation program encoded on a computer readable medium readable by the controller. The program includes codes readable by the controller for directing the controller to execute the method described herein. For example, the program causes the controller to maintain the temperature of the sea water at each step for a predetermined period of time, based on temperature information of the sea water received from the temperature sensors while increasing the predetermined period of time maintained at each step of decreased temperature. The program also causes the controller to use the information on the dissolved oxygen level received from the oxygen sensors, and cause the period of maintaining constant temperature of the sea water at each step to be gradually decreased after the temperature of the sea water at which there is no deviation of the level of the dissolved oxygen consumed by the aquatic animals has been reached.

Thus, the PC (9) in the apparatus for inducing artificial hibernation of marine animals operatively controls the heat exchanger (2) or the cooler (5) to thereby bring or induce the aquatic animals into a dormant state of hibernation. To this end, the apparatus for inducing artificial hibernation of marine animals may further include a compressor (3) and a pressure controller (4) for controlling the operation of the heat exchanger (2) or the cooler (5), and may further include a temperature controller (7) for controlling the temperature sensor. The PC (9) may control the pressure controller (4), the temperature controller (7), the heat exchanger (2) or the cooler (5).

The apparatus can be used with fresh water or salt water. Each pipe and constituent element contacting the water is made of PVC (Polyvinyl Chloride) material or titanium material which is resistant to degradation (e.g. rusting) in salt water. The apparatus may be largely divided into an artificial dormant chamber (15), a cooling apparatus and a water temperature control apparatus (PC).

Inner and outer walls of the artificial dormant chamber (15) are made of plastic material or titanium resistant to degradation in salt water, and are filled at a midsection thereof (thickness of 5 cm) with adiabatic epoxy for blocking heat from the outside, and include a cover. The chamber (15) has a volume of 500 liters into which 400 liters of water may be filled. Fine water temperature adjustments and changes made inside the chamber (15) both measured at PC (9), and the temperature controller (7) may be corrected by two temperature sensors (Pt 100 temperature sensors 11, 12). The dissolved oxygen (DO) inside the chamber (15) is measured by the oxygen sensor (10. Multiline P4, WTW, Germany) connected to the PC (9), and speed of the water (45 liter/min) is controlled by an inlet (14) and an outlet (13) disposed at the chamber (15) thereby maintaining the oxygen saturation of the water at 100%.

The chamber (15) may include a fishing net (16) capable of harvesting the aquatic animals from the sea water. To this end, the fishing net (16) may be first installed in the chamber (15) before the aquatic animals are received in the chamber (15). Flat fish such as halibut are difficult to catch if they are lying flat on the floor, and it is easy to harvest the halibut laying inside the fishing net (16) without much stress just by lifting the fishing net (16).

A cooling device for the apparatus includes a pump (1) capable of processing 45 liters per minute, a heat exchanger (2) capable of heat exchanging 12,000 kcal per hour, a 2-horse power compressor (3), a pressure controller (4) and a cooler (5). The direction of sea water passing through the cooling device is shown in solid lines in FIGS. 10 and 11. It is important that refrigerant circulating in the heat exchanger (2), the compressor (3) and the pressure controller (4) is maintained at high pressure and

low temperature (-25 degrees) in order to lower the temperature of sea water coming into the artificial hibernation chamber (15) using the cooling device. The circulation process of the refrigerant is illustrated in solid lines in FIGS. 10 and 11.

5 If the temperature of sea water passing through the heat exchanger (2) is too low, a problem may occur in the heat exchanger (2). Small-diameter pipe in the heat exchanger (12,000 k cal/h) through which the sea water passes can be ruptured if freezing conditions occur inside the pipe. Therefore, it is preferred that pressure of the compressor (3) be automatically adjusted to lower the temperature of the refrigerant to prevent the heat exchanger (2) from freezing, if the temperature of sea water passing through the pipe of the heat exchanger (2) goes down below a predetermined level. For example, if an inner temperature of the artificial hibernation chamber (15) is high (i.e., 13 ~ 4 degree Celsius), the compressor (3) increases pressure to maintain the temperature of refrigerant at -25 degree Celsius, and if the temperature of sea water inside the artificial hibernation chamber (15) is low at approximately 1 degree Celsius, the compressor (3) decreases the pressure to maintain the temperature of the refrigerant at -1 degree Celsius, whereby the freezing of the heat exchanger (2) can be avoided (freezing temperature: -1.93 degree Celsius at salinity of 24.7‰).

20 An LED (Light Emitting Diode) lamp acts as an indicator for malfunctions of the cooling system and is mounted at an upper end of the apparatus to allow quick response to any problems. The temperature of the artificial hibernation chamber (15) is also automatically adjusted by the PC (9) and the temperature controller (7) according to the program executed by the PC (9). The PC (9) may show whether the temperature adjustment of the artificial hibernation inducement process is in normal operation. It is preferred that one cycle of artificially induced hibernation be in the range of 14 ~ 20 hours depending on the initial temperature, fish type and the fish size.

30 The PC (9) controls the heat exchanger (2) or the cooler (5) to automatically induce the artificial dormant state of hibernation of marine animals inside the artificial hibernation chamber (15). The artificial inducement of hibernation of marine animals is the same as elucidated above wherein the temperature of the sea water lowered at

each step can be maintained for a predetermined period of time, based on sea water temperature information received from the temperature sensors (11, 12) by the PC (9) while increasing the predetermined period of time maintained at each phase of decreased temperature. Based on the information on the dissolved oxygen level received from the oxygen sensors, the time during which the temperature of the sea water is maintained constant at each step is gradually lowered at each step after reading the temperature at which there is no deviation of the dissolved oxygen level. Accordingly, the PC (9) automatically induces a dormant state of hibernation of marine animals.

Once the marine animals are induced into a dormant state of hibernation by adjusting the temperature of sea water and step time by the apparatus, the marine animals may be put into a box capable of blocking the artificial hibernation induced marine animals from outside heat, i.e., the marine animals may be covered with moistened coverings to ensure a constant humidity, and the box may be sealed to allow the artificially hibernated marine animals to be hauled long distances for distribution.

If outside air or heat is introduced into the box containing the marine animals, the temperature inside the box increases which can "wake up" the artificially hibernating marine animals earlier than desired to an environment that is dangerous to their survival in their waking state or even poisonous to the marine animals, which can kill a large number of them. It is desirable therefore to use boxes that can block the introduction of outside air or heat in order to keep the artificial dormant state of hibernation for a desired period of time. The inner temperature of the boxes is not particularly restricted but it has been ascertained that the inner temperature in the boxes should be kept in the range of 1 to 2 degrees Celsius to maintain the artificially induced dormant state of the marine animals.

Although there is no need of water for transportation as the marine animals are induced into artificial dormancy of hibernation, wetted coverings may be used for keeping humidity necessary for survival of the marine animals. In other words, it was found to be most desirable to cover the marine animals with soaked Korean traditional paper (hand-made from mulberry trees) to keep the humidity at 90% or more.

As described above, use of the endogenous rhythms of the marine animals facilitates artificially bringing the marine animals into a dormant state of hibernation, and as a result, a simple packaging of the marine animals in boxes under waterless conditions can facilitate a long survival rate (viability) of hibernating aquatic animals.

5
Preferably, the artificially induced dormant marine animals in the tightly sealed boxes are transported to market destinations, where the boxes are opened to allow the marine animals to be stocked into water having a temperature in the range of 7 to 9 degrees Celsius where they wake up from the dormant state of hibernation in a few
10 seconds or within about 10 minutes, depending on the size of the marine animals.

Effectively, the embodiments described observe the endogenous rhythms of marine animals, and artificial hibernating conditions are induced through several steps of temperature changes to stop the endogenous rhythms for a long period of time to
15 facilitate transportation and subsequent restoration of original biorhythms thereby maintaining the animals alive.

Now, another embodiment of the present invention will be described in detail with reference to the attached drawings. It is needless to say that the present invention is
20 not limited to, but may be better understood by the following embodiment. It is also to be understood that both the foregoing general description and the following embodiments are exemplary and explanatory, and therefore are not to be considered as limiting the scopes as claimed.

25 Live halibut harvested from Jeju Island in the southern part of Korea and bought through Ansan Agro-fishery Market were used to test the function of the embodiments described herein. The total experimental live fish population was 290, where a total of 63 individuals were wrapped and transported in a vinyl envelope or old newspaper according to the usual transportation method, and a total of 227
30 individuals were employed for artificial inducement of dormant hibernation for transport using the waterless conditions according to the embodiments described.

RESPIRATORY ACTIVITIES AND ANALYSIS OF ENDOGENOUS RHYTHMS OF HALIBUT

In order to understand the artificially induced dormant state of hibernation using endogenous biorhythms of marine animals, the metabolic activities associated with endogenous biorhythms of subject fish (alive) were analyzed.

Experimental conditions are very important for measuring the endogenous biorhythms of live fish. The experimental conditions where at least two or more external environmental conditions are kept constant (Palmer 1995) may be considered endogenous biorhythms. Fish have eyes, and melanin pigmentation therein may be affected by light which can have an influence on behavior or metabolic activities of the fish, making it difficult to observe the endogenous biorhythms. BOD incubators (VS 1203P5N, Vison Co., Seoul, Korea) capable of blocking light and keeping the water temperature constant (FIG.4: 19 degrees, FIG.6: 21.5 degrees) were used. Analysis of endogenous biorhythms relative to respiratory activities of cultured halibut was performed using an AIFR (Automatic Intermittent-Flow-Respirometer; FIG.3) developed by the current inventors. Respiratory data continuously measured for 135 hours by the AIFR has shown in a 2% moving average using a computer program (KaleidaGraphy, Synergy Software, Essex Junction, VT, USA) according to the Least-squares Method (FIGS.4 and 6).

Periodical analysis of the endogenous biorhythms relative to respiratory activities of halibut was made using MESA (Maximum Entropy Spectral Analysis) program. Continuous data taken at a constant time interval are needed for endogenous biorhythm periodic analysis, and numerical values taken at 10 minute intervals were transformed to mean values using the data measured by the AIFR, and then analyzed by the MESA program to obtain periodic analysis data of the type shown in FIG.5.

As shown in FIG.7, cultured halibut have a period of 24.8 hours, almost conforming to a period of 24 hours. However, wild marine fish stocks or marine animals have shown quite different biorhythm periods when respirations thereof were continuously observed by the AIFR, as illustrated in FIG.6.

FIG.6 illustrates oxygen consumption as a result of respirations of manila clams (*Ruditapes philippinarum*) continuously measured in BOD incubators (under dark environment and constant water temperature of 21.5 degrees) for 260 hours by the AIFR. As a result of analysis using a 2% moving average, there were two strong peaks per day, and when the data was analyzed using the MESA program it could be seen that, the respirations of manila clams were greatly affected by tidal influence of 12.2 hours as shown in FIG.7. A period of 25.1 hours was also observed. As understood from the endogenous biorhythm experiments of manila clams, it can be seen that biorhythms of marine animals are different according to habitat.

Generally, if the respirations of marine animals are measured by the AIFR for a long time, the endogenous biorhythms of the marine animals can be observed, which may be important fundamental data for inducing an artificially induced dormant state of hibernation of marine animals.

CHANGES OF MEAN OXYGEN CONSUMPTION OF HALIBUT IN RESPONSE TO DECREASE IN SEAWATER TEMPERATURE

Based on respiratory activities and endogenous biorhythm analysis as described herein, on analytical data of halibut, a sea water temperature at which changes of oxygen consumption by marine animals were greatly reduced, or changes of oxygen consumption were almost zero were determined by lowering the temperature of sea water containing the marine animals and using the apparatus for inducing artificial hibernation of marine animals according to the embodiments described.

As a result, there has been no problem of survival for halibuts stored at 13 degree Celsius even if the temperature was reduced to 10 degrees, as evidenced in FIG.8. As illustrated in FIG.9, the sea water temperature was kept at 13 degrees for 10 minutes, and the duration of each step was increased with each decrease in water temperature, i.e., approximately 20 minutes at 12 degrees, approximately 30 minutes at 11 degrees. The time duration at 6 degrees was increased to 120 minutes which is 12 times the exposure period (10 minutes) at the initial 13 degree water temperature, to 180

minutes at 5 degrees Celsius, and to 260 minutes at 4 degrees Celsius (where biorhythms cease) which is the longest exposure time in order to minimize stress. Subsequently, the exposure time was gradually reduced as the sea water temperature was decreased. In other words, halibut were manipulated to stay alive in the sea water by reducing the exposure time, i.e., 180 minutes at 3 degree Celsius, 120 minutes at 2 degree Celsius and 20 minutes at 1 degree Celsius sea water temperatures.

Finally, the halibut were exposed for 15 minutes at 0.2 degree Celsius below zero.

Based on a graph the changes of mean oxygen consumption rate of marine animals in response to the water temperature as illustrated in FIG.8, Table 1 is provided to define maximum and minimum values of oxygen consumption consumed by the halibut at different temperatures, the amplitude of changes in oxygen consumption, and inclinations of mean oxygen consumption rates at each temperature.

TABLE 1: AMPLITUDES OF OXYGEN CONSUMPTION BY HALIBUT AND INCLINATIONS AT EACH TEMPERATURE SECTION

Temp. (°C)		13	10	8	7	6	5	4.5	4	3	2	1
Oxygen consumption (ml O ₂ kg ⁻¹ WW h ⁻¹) amplitudes (by 5% moving average) and Average	Maximum (A)	23.8	17.7	16.6		12.5	8.4		6.2	6.1	6.1	6.1
	Minimum (B)	11.6	10.8	10.2		7.0	6.1		6.1	6.1	6.1	6.1
	Amplitude (A-B)	12.2	6.9	6.4	6	5.5	2.3	1.1	0.1	0.0	0.0	0.0
	Average (C)	17.7	14.3	13.4		9.8	7.3		6.2	6.1	6.1	6.1
Inclination for each temperature section (A-B)		1.77	0.25	0.25		0.25	2.7		0.05			

5 As shown in Table 1, an inclination in response to oxygen consumption amplitude of halibut stands at 1.77 when the temperature decreases from 13 to 10 degrees Celsius. The inclination stands at 0.25 for both cases of the temperatures being reduced from 10 to 8 degrees Celsius, and 8 to 6 degrees Celsius, which is a smaller value compared with that when the temperature is lowered from 13 to 10 degrees Celsius. Consequently, it may be seen that where the temperature decreased from 10 to 6 degrees Celsius there were no big changes of respiration and metabolic activity of the

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halibut. Where the temperature decreases from 6 degrees to 4 degrees a robust inclination of 2.7 occurs, which confirms that there is a great change of metabolic activities at this temperature range. The oxygen consumption was almost constant ($6.1 \text{ ml O}_2 \text{ kg}^{-1} \text{ WW h}^{-1}$) at temperatures below 4 degrees Celsius, and inclination stood at 0.05, which showed that such temperature changes had little influence on the oxygen consumption at such conditions.

EXPERIMENTS OF ARTIFICIAL HIBERNATION USING HALIBUTS AND OTHER LIVE FISH

Fish that were not subjected to artificial hibernation as described herein and two weight categories of live halibut that were subjected to artificial hibernation as described herein were packaged. The fish not subjected to artificial hibernation were packaged in traditional Korean paper (vinyl or newspaper). The fish that were subjected to artificial hibernation were simply packaged in boxes without such paper.

The boxes were maintained at an inner temperature of 5 degrees Celsius and were sealed and stored. As the storage time progressed, the survival rate (viability) of the halibut was monitored, the result of which is shown in the following Table 2.

TABLE 2: EXPERIMENTAL RESULTS OF ARTIFICIAL HIBERNATION USING LIVE HALIBUT AND OTHER LIVE FISH

Experiments	Populations	Individual weight	Status of pre-treatment for temperature changes	Utilization of traditional Korean Paper	Waterless condition maintenance period	Survival rate
Existing method (no use of artificially induced hibernation)	63	820 – 1060 g	x	x	12-15 hours	20-30%
Induced artificial hibernation & waterless condition packaging techniques	140	720 – 1340 g	0	0	18-24 hours	90-100%
Induced artificial hibernation & waterless condition packaging techniques	87	2020 – 2740 g	0	0	18-24 hours	90-100%

5 As evidenced in Table 2, the halibut and other live fish subjected to the induced artificial hibernation and waterless condition packaged transport method according to the present invention have a longer waterless condition time than that of the transport

method of live fish wrapped in vinyl or old newspaper according to the previous common method.

5 While certain novel features of this invention have been shown and described and are pointed out in the annexed claims, it is not intended to be limited to the details above, since it will be understood that various omissions, modifications, substitutions and changes in the forms and details of the device illustrated and in its operation can be made by those skilled in the method without departing in any way from the basic nature of the present invention.

10 The terms and expressions which have been employed in the foregoing specification are used therein as terms of description and not of limitation, and there is no intention, in the use of such terms and expressions, of excluding equivalents of the features shown and described or portions thereof, it being recognized that the scope of the invention is defined and limited only by the claims which follows.

15 There is an advantage in the method and apparatus for inducing artificial hibernation of marine animals thus described according to the present invention in that marine animals can be artificially induced to a dormant state of hibernation and as a result, the artificially induced hibernating marine animals in waterless conditions exhibit a longer survival rate (viability) than fish packaged using a conventional method. The gradual step-by-step changes of sea water temperature described herein can artificially induce hibernation of marine animals enabling them to be maintained in waterless conditions.

**THE EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSIVE
PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:**

1. A method for inducing artificial hibernation of fin fish in sea water contained in a
5 container, the method comprising:

(a) monitoring the amount of mean oxygen consumption by the fin fish in the
sea water for a first pre-determined period of time;

10 (b) gradually reducing the sea water temperature on a step-wise basis in a
first plurality of successive steps wherein in each step the sea water
temperature is kept constant for a respective predetermined period of
time, and wherein said respective predetermined period of time is
15 increased with each successive step until a sea water temperature is
reached wherein mean oxygen consumption by the fin fish is
approximately constant; and

(c) then continuing to gradually reduce the sea water temperature on a further
step-wise basis for a second plurality of successive steps and gradually
20 reducing the respective predetermined periods of time associated with
each step of said second plurality until artificial hibernation of the fin fish
occurs.

2. A method for inducing artificial hibernation of fin fish in sea water contained in a
25 container, the method comprising:

(a) monitoring the amount of mean oxygen consumption by the fin fish in the
sea water for a first pre-determined period of time to determine an initial
oxygen consumption value;

30 (b) gradually reducing the sea water temperature on a step-wise basis in a
first plurality of successive steps, until the respiratory rate or endogenous
biorhythm of the fin fish indicates the fin fish is most stressed wherein in
each step the sea water temperature is kept constant during a respective

predetermined period of time and wherein said respective predetermined period of time is increased with each successive step; and

- (c) then continuing to gradually reduce the sea water temperature on a further step-wise basis for a second plurality of successive steps wherein the respective predetermined period of time that is maintained during each step-wise reduction of sea water temperature is reduced, starting from a step in which sea water temperature is such that oxygen consumed by the fin fish is 1.5 to 4 times smaller than said initial oxygen consumption value or such that a difference between a maximum and a minimum of oxygen consumption by the fin fish, is in the range of $6.0 \text{ ml O}_2 \text{ kg}^{-1} \text{ WW h}^{-1} \sim 0.0 \text{ ml O}_2 \text{ kg}^{-1} \text{ WW h}^{-1}$.

3. A method for inducing artificial hibernation of fin fish in sea water contained in a container, the method comprising:

- (a) monitoring the amount of mean oxygen consumption by the fin fish for a first predetermined period of time while holding the sea water temperature at a first pre-determined temperature;
- (b) gradually reducing the sea water temperature to a second predetermined temperature for a second predetermined period of time that is 10 to 25 times longer than the first predetermined period of time, and wherein the mean oxygen consumption during the second predetermined period of time is 1.5 to 2.5 times lower than the amount of mean oxygen consumption during the first predetermined period of time; and
- (c) then continuing to gradually reduce the sea water temperature to a third predetermined temperature, for a third predetermined period of time that is 26 to 100 times longer than the first predetermined period of time, and wherein the mean oxygen consumption is 3 to 4 times lower than the mean oxygen consumption during the first predetermined period of time.

4. A method for inducing artificial hibernation of fin fish kept in sea water in a container, the method comprising:

determining an initial oxygen consumption of the fish at an initial temperature, for a first period of time; and

gradually lowering the water temperature to a second temperature for a second period of time, where the second temperature is a temperature at which said oxygen consumption is 3 to 4 times lower than the initial oxygen consumption, and the second period of time is 10 to 100 times longer than the first period of time.

5. A method for inducing artificial hibernation of fin fish kept in sea water in a container, the method comprising:

maintaining the sea water at a first temperature for a first period of time;

lowering the sea water temperature to a second temperature at which a difference between the maximum and minimum oxygen consumption by the fin fish is in the range of $6.0 \text{ ml O}_2 \text{ kg}^{-1} \text{ WW h}^{-1} \sim 1.0 \text{ ml O}_2 \text{ kg}^{-1} \text{ WW h}^{-1}$;

keeping the sea water at the second temperature for a second period of time which is 10 to 25 times longer than the first period of time;

gradually lowering the water temperature to a third temperature where a difference between the maximum and minimum oxygen consumption by the fin fish is in the range of $1.1 \text{ ml O}_2 \text{ kg}^{-1} \text{ WW h}^{-1} \sim 0.0 \text{ ml O}_2 \text{ kg}^{-1} \text{ WW h}^{-1}$; and

keeping the sea water at the third temperature for a third period of time which is 26 to 100 times longer than the first period of time.

6. A method for inducing artificial hibernation of fin fish kept in sea water in a container, the method comprising:

maintaining the sea water at an initial temperature for a first period of time;

gradually lowering the water temperature to a second temperature where a difference between the maximum and minimum oxygen consumption by the fin fish is in the range of $1.1 \text{ ml O}_2 \text{ kg}^{-1} \text{ WW h}^{-1} \sim 0.0 \text{ ml O}_2 \text{ kg}^{-1} \text{ WW h}^{-1}$; and

keeping the sea water at the second temperature for a second period of time that is **10** to **100** times longer than the first period of time.

7. The method as claimed in claim 6, wherein gradually lowering the sea water temperature includes gradually decreasing the sea water temperature in steps, wherein successive steps have respective successively increasing time periods.

8. The method as claimed in claim 3 or 5, wherein the first temperature is in the range of **14 ~ 12** degree Celsius, the second temperature is in the range of **7 ~ 5** degree Celsius, and the third temperature is in the range of **5 ~ 3** degrees Celsius.

9. The method as claimed in claim 6, wherein the initial temperature is **13** degrees Celsius, and the second temperature is **4** degrees Celsius.

10. A method for transporting fin fish, the method comprising:

inducing an artificial hibernation state of said fin fish by:

maintaining said fin fish in sea water for a predetermined period of time;

gradually decreasing the sea water temperature according to predetermined temperature steps in a stepwise process while gradually

increasing the time of maintaining the sea water temperature constant at each predetermined temperature step until the seawater has reached a first pre-defined temperature, then;

continuing to gradually decrease the seawater temperature in predetermined temperature steps while gradually decreasing the time of maintaining the sea water temperature constant at each predetermined temperature step until the seawater has reached a second pre-defined temperature, such that said fin fish enter said hibernation state; and

transporting said fin fish in said hibernated state.

11. A method according to claim **10**, wherein said sea water temperature is gradually lowered by approximately 1, 2, or 3 degree(s) Celsius per predetermined temperature section.

12. A method according to claim **10** or **11**, wherein the predetermined periods of time at each predetermined temperature step are approximately 10, 20, 30, 40, 50, 60, 80, 120, 180, 260, 180, 120, 20 and 15 minutes, respectively.

13. The method as claimed in any one of claims **1** to **12**, wherein the fin fish is live halibut or other live fish.

14. An apparatus for inducing artificial hibernation of fin fish, the apparatus comprising:

an artificial dormant chamber for containing sea water including the fin fish;

a heat exchanger or a cooler for gradually lowering a temperature of the sea water discharged from the artificial dormant chamber according to a predetermined schedule and introducing the temperature-lowered sea water back into the artificial dormant chamber;

temperature sensing means for sensing the temperature of sea water contained in the artificial dormant chamber;

5 an oxygen sensor for measuring the level of dissolved oxygen contained in the sea water;

a controller for controlling the heat exchanger or cooler; and

10 a computer readable medium encoded with codes for directing the controller to control the heat exchanger or cooler to gradually reduce the sea water temperature on a step-wise basis in a first plurality of subsequent steps in accordance with the amount of oxygen consumed by said fin fish during each step, wherein in each step the sea water temperature is kept constant for a
15 predetermined period of time, said predetermined period of time being increased with each successive step, the temperature being reduced until a sea water temperature is reached wherein mean oxygen consumption by the fin fish is approximately constant.

20 15. The apparatus as claimed in claim 14, wherein the artificial dormant chamber includes a fishing net capable of harvesting the fin fish from the sea water.

DRAWINGS

FIG. 1

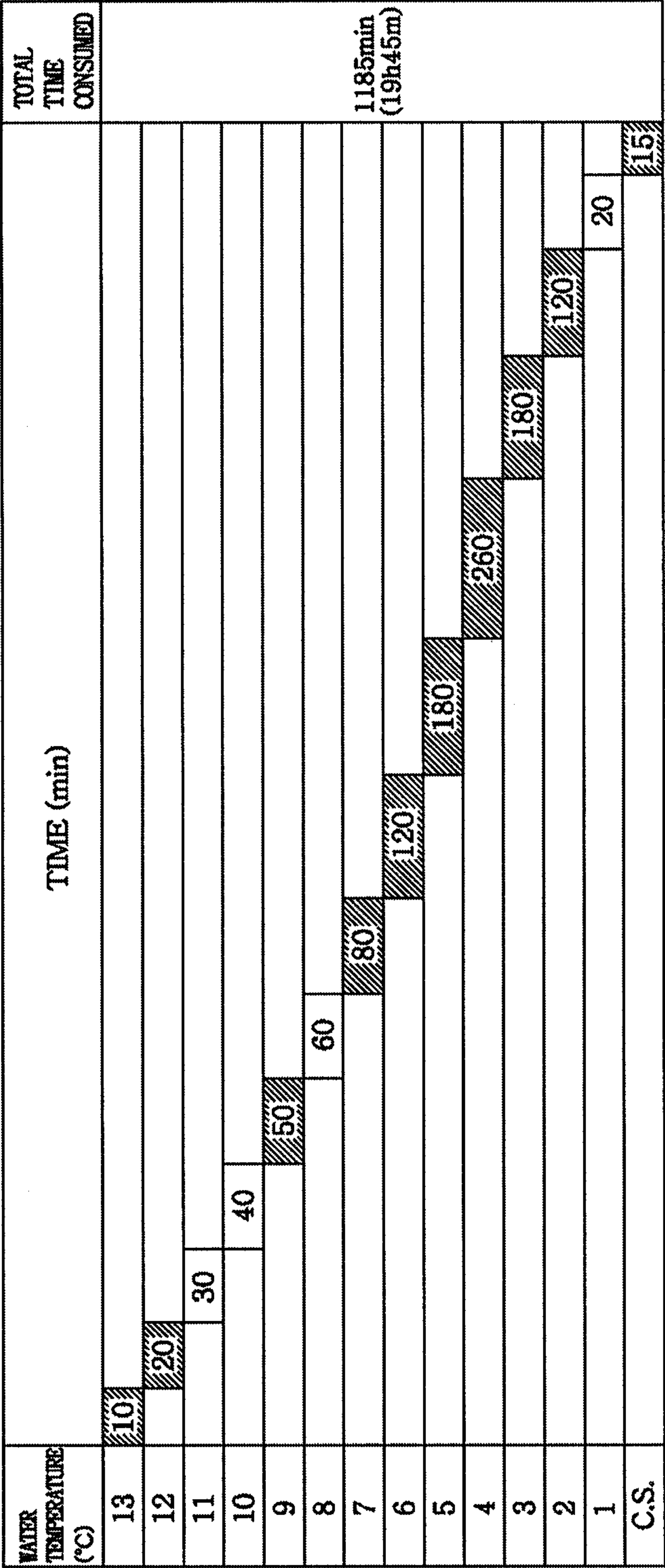


FIG. 2

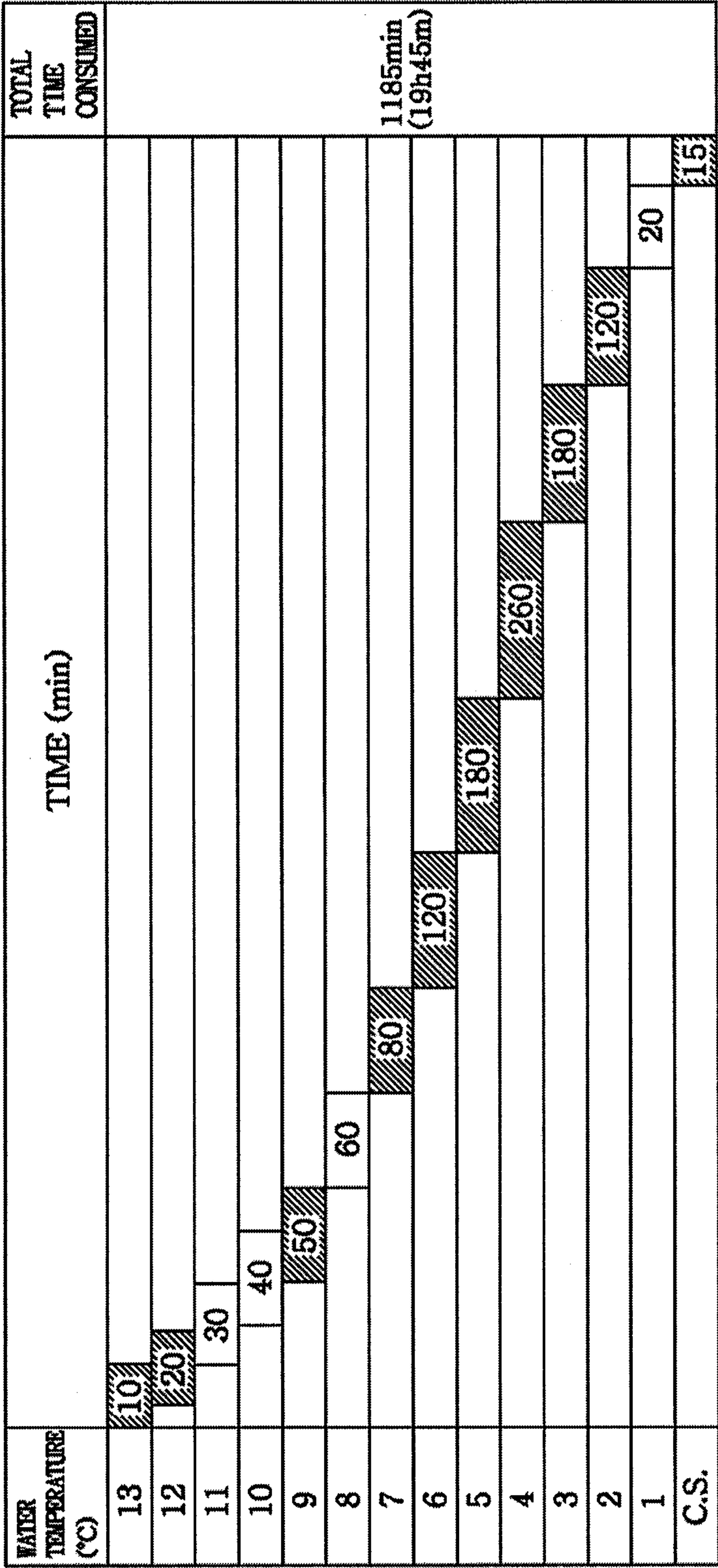


FIG. 3

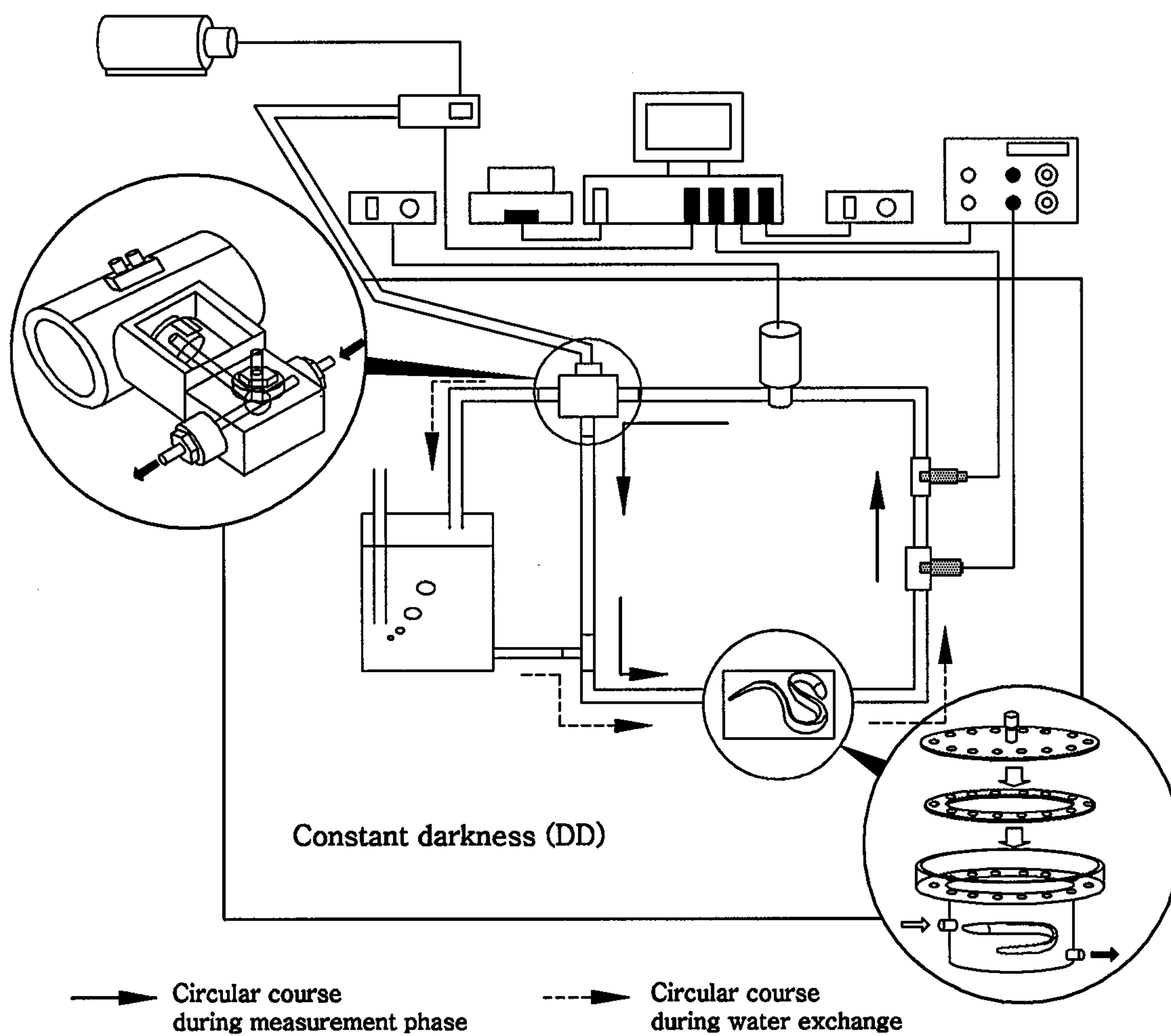


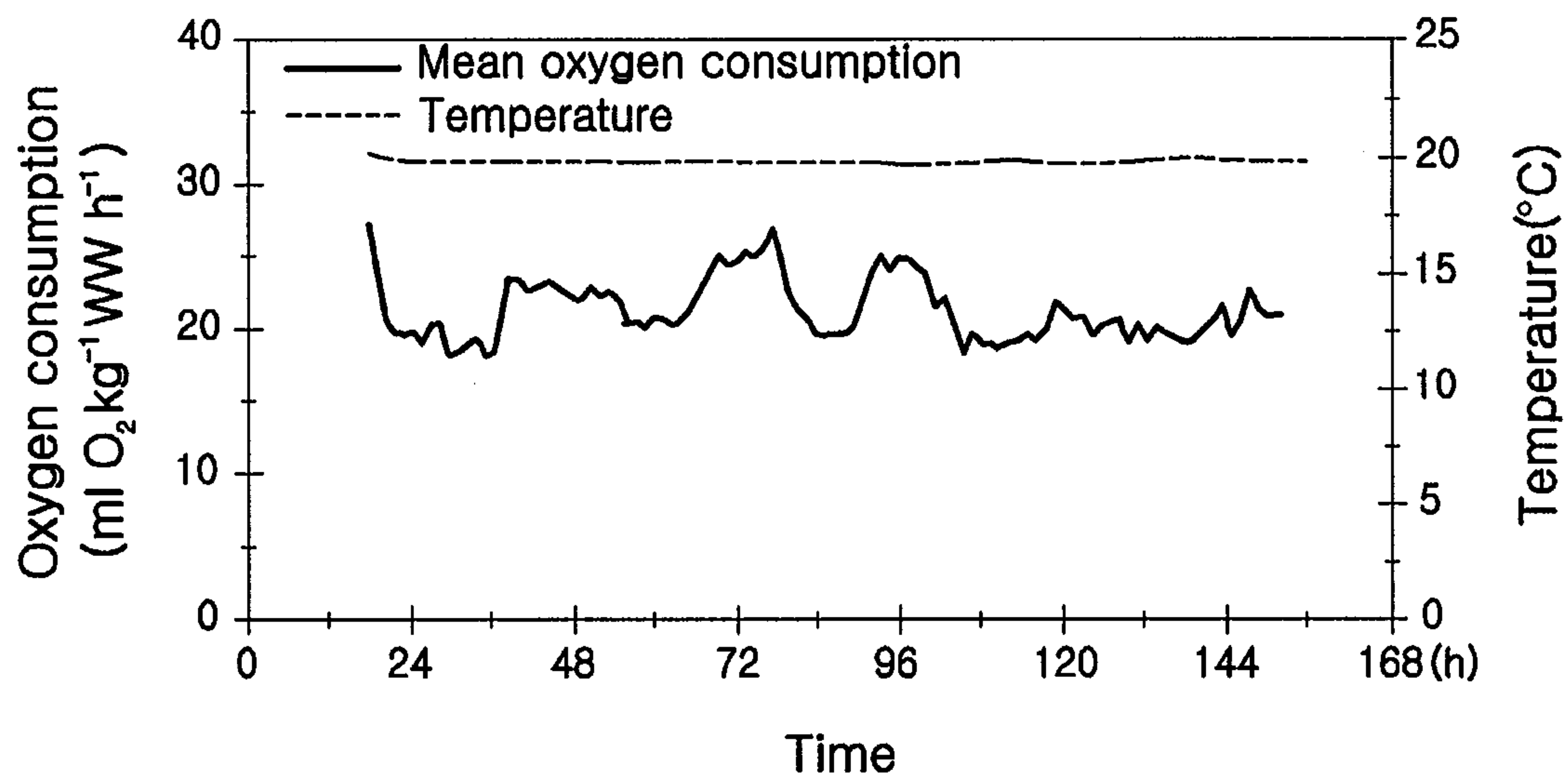
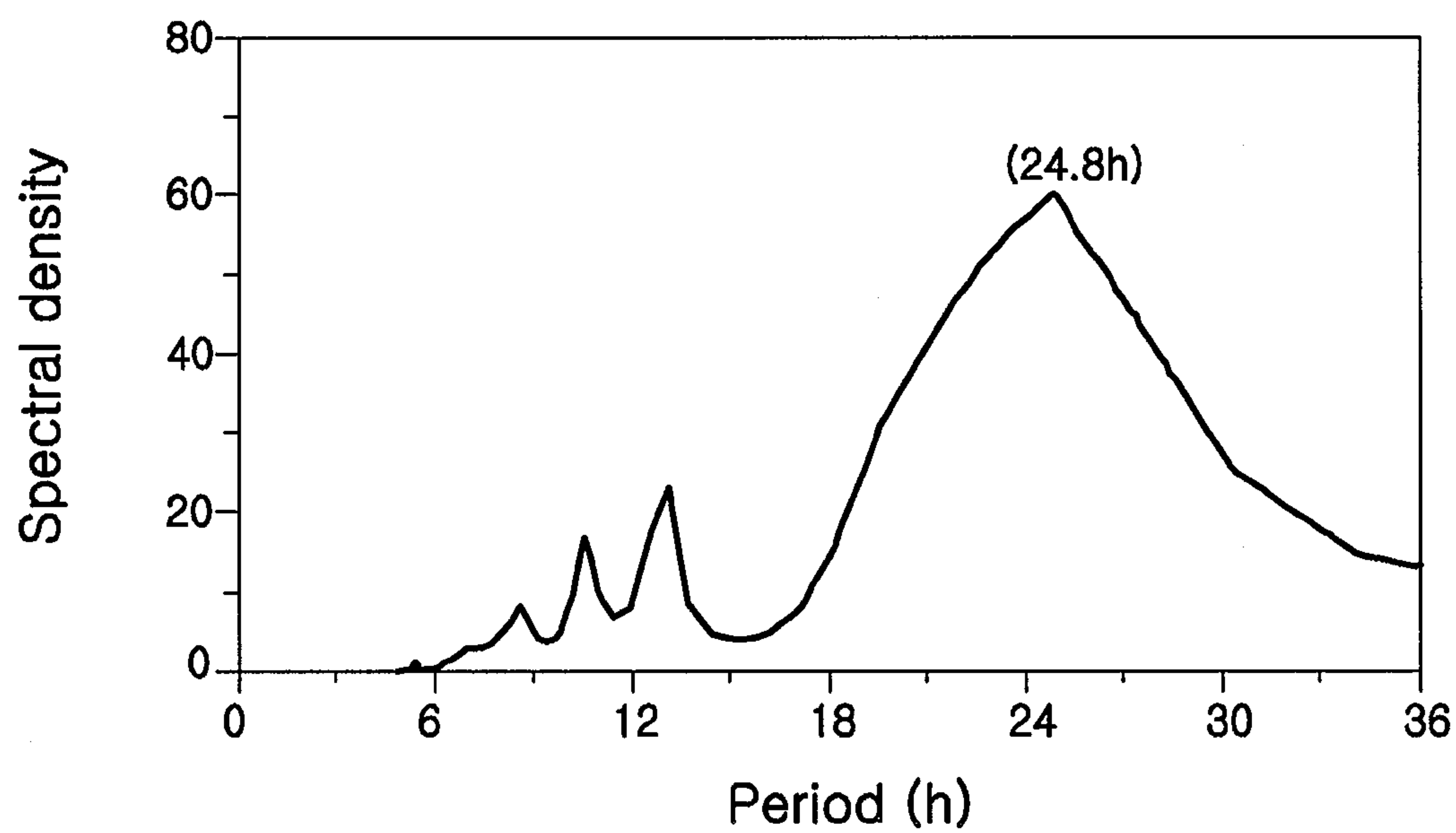
FIG. 4**FIG. 5**

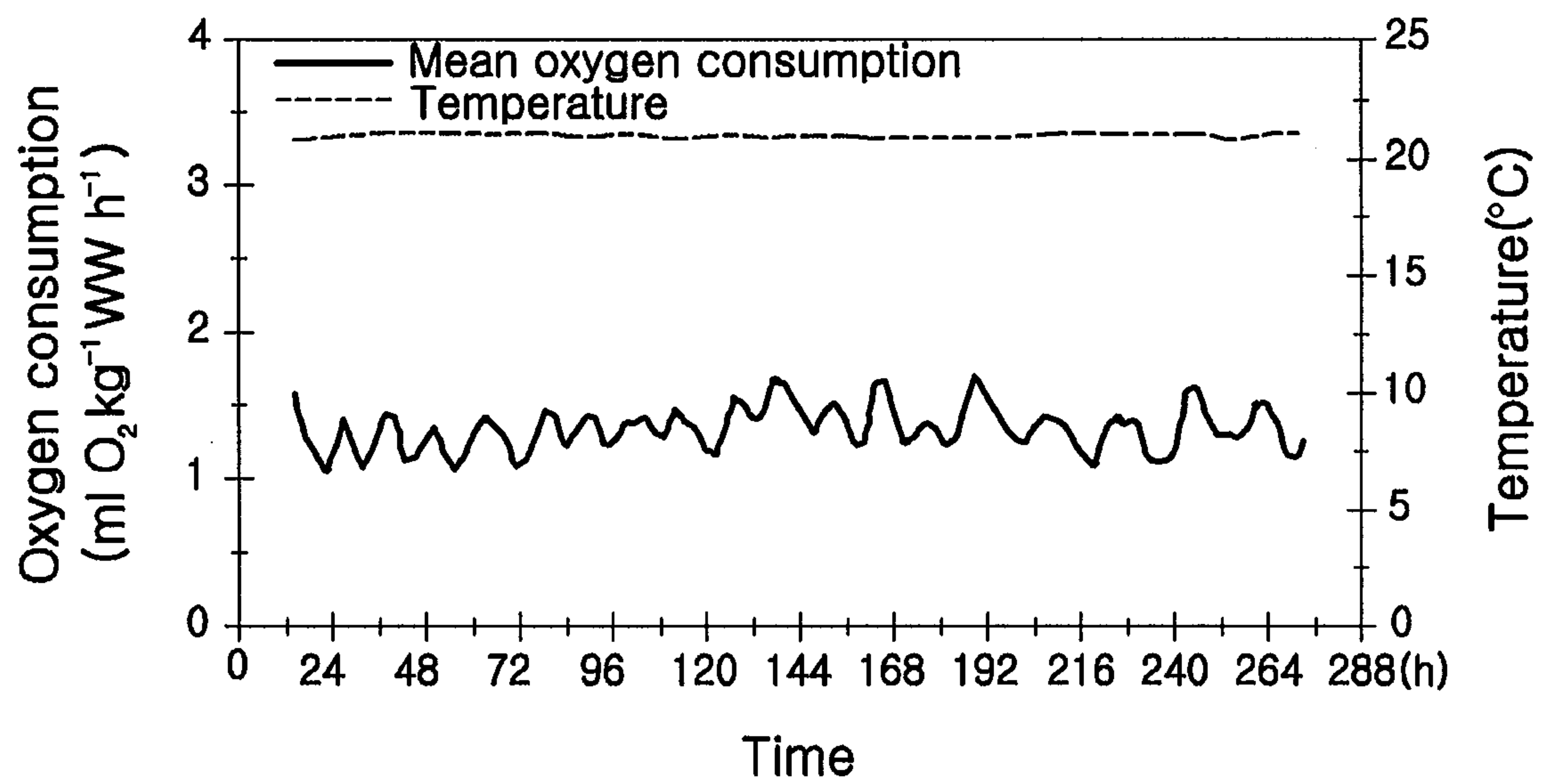
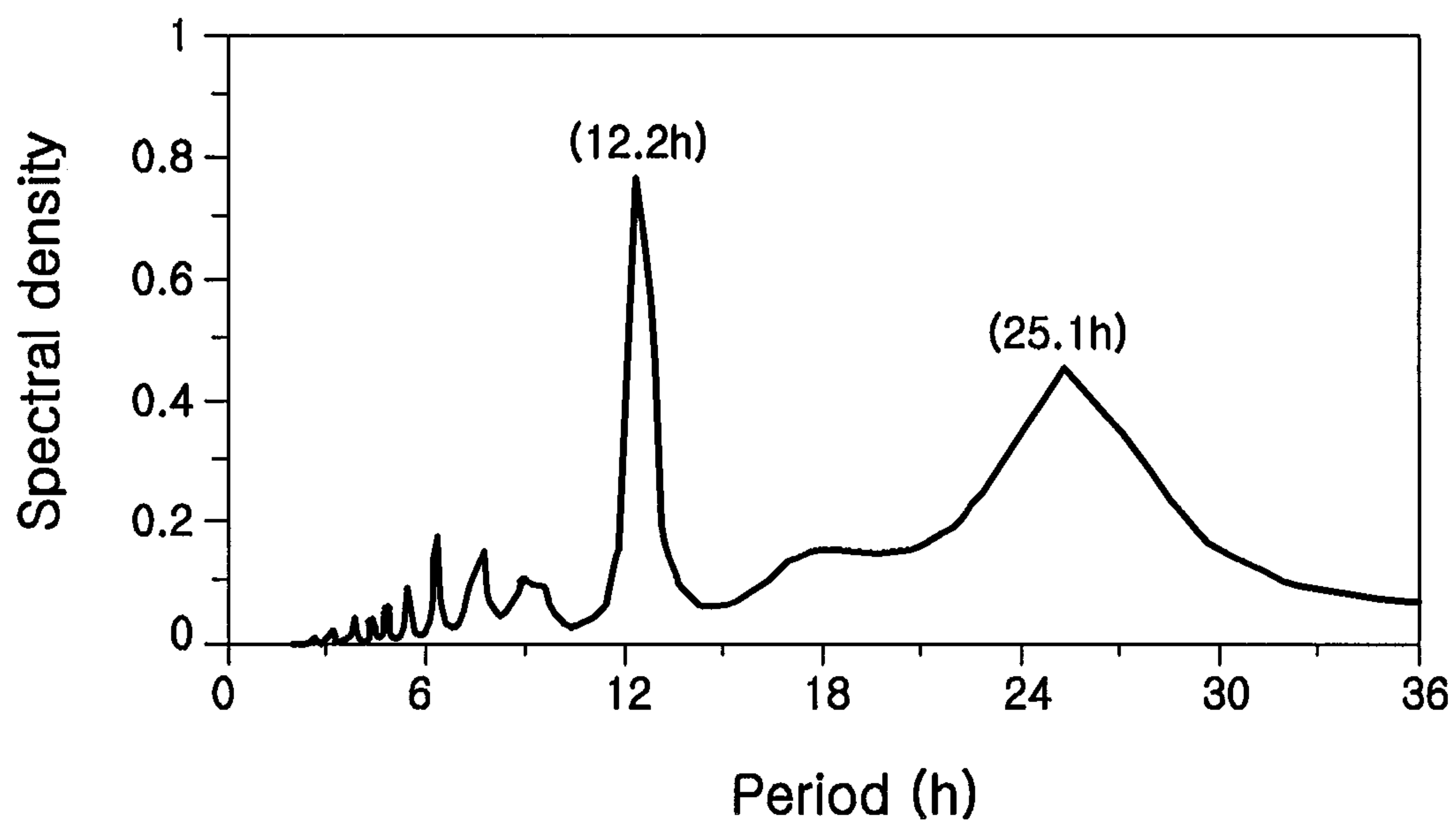
FIG. 6**FIG. 7**

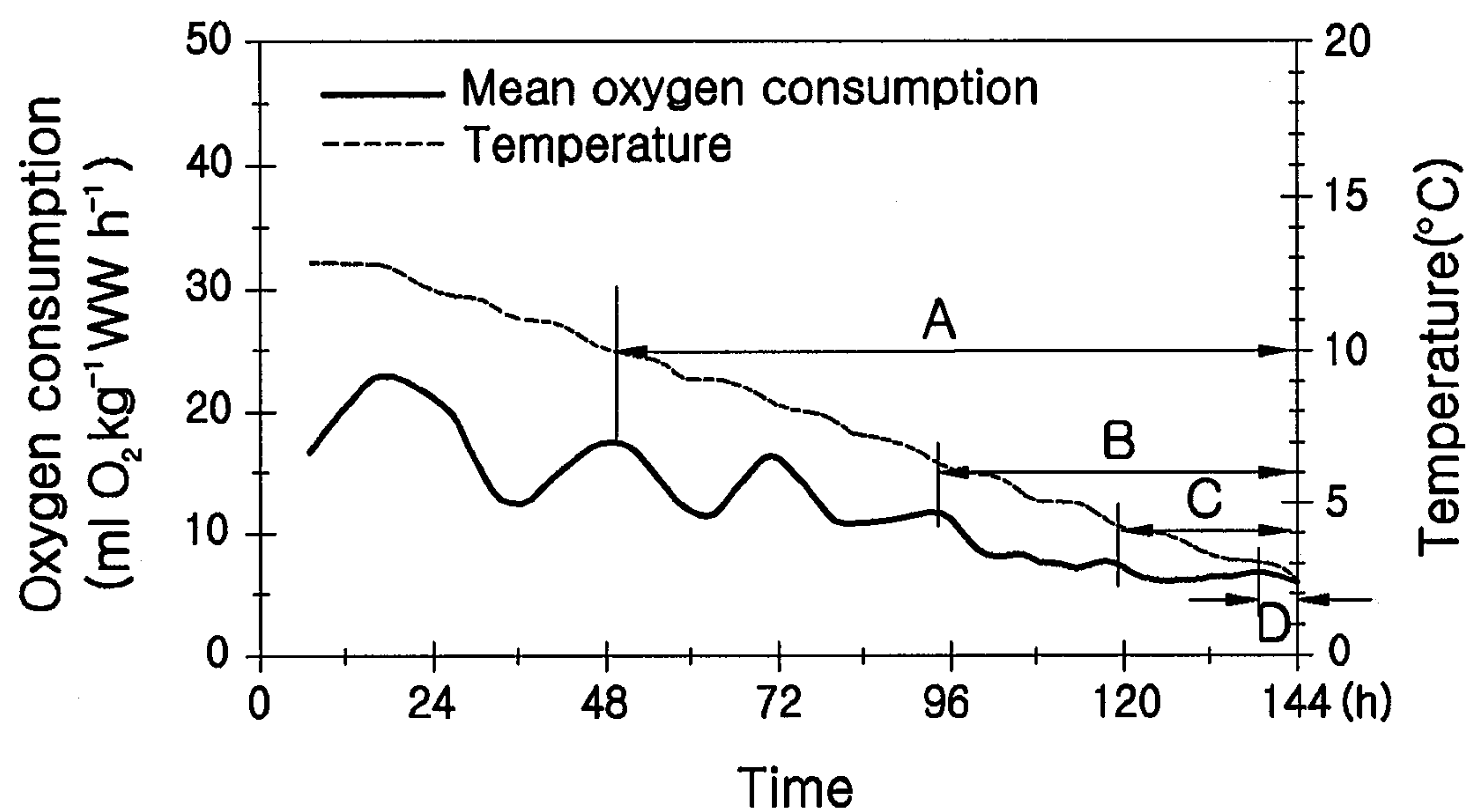
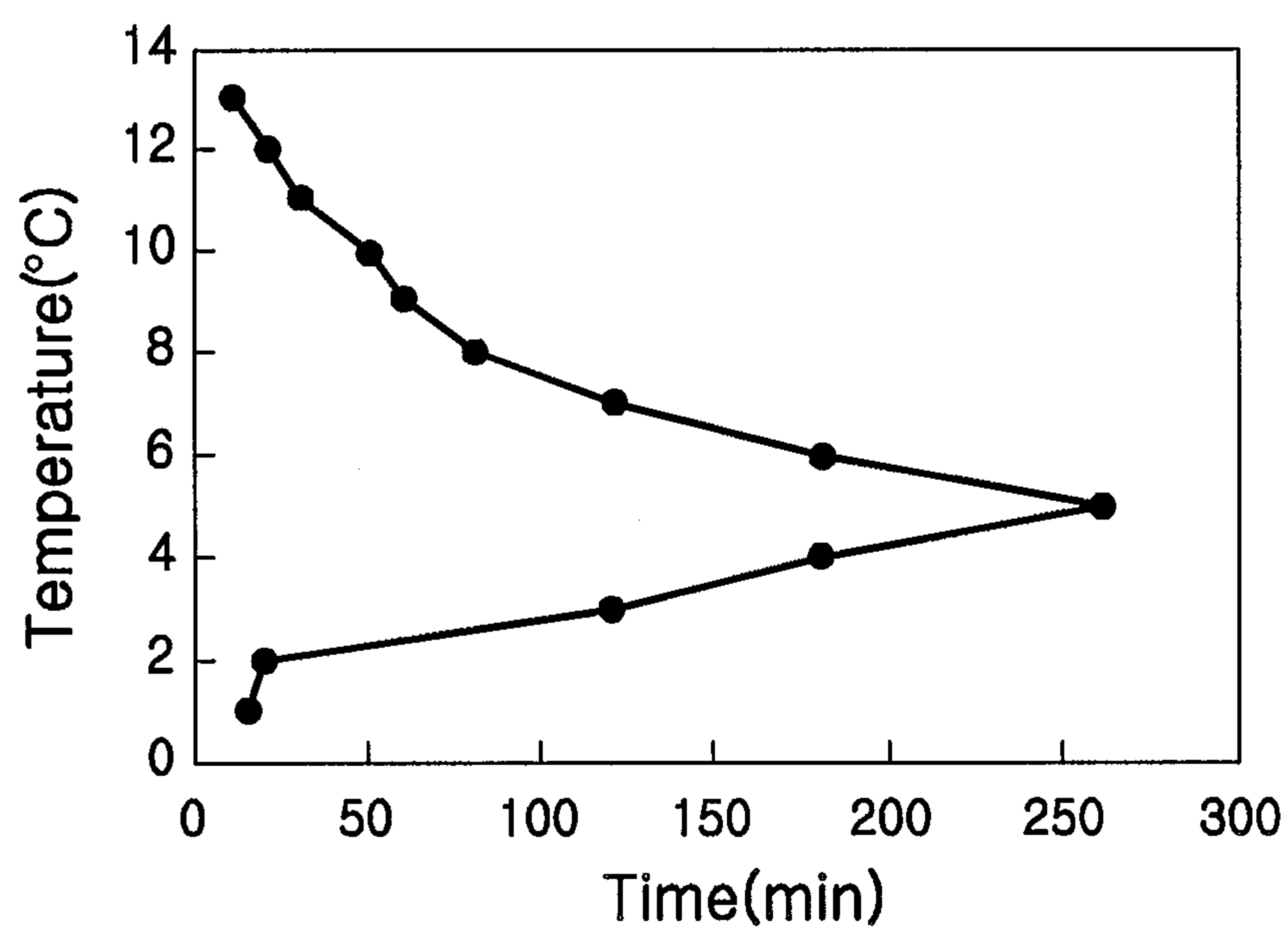
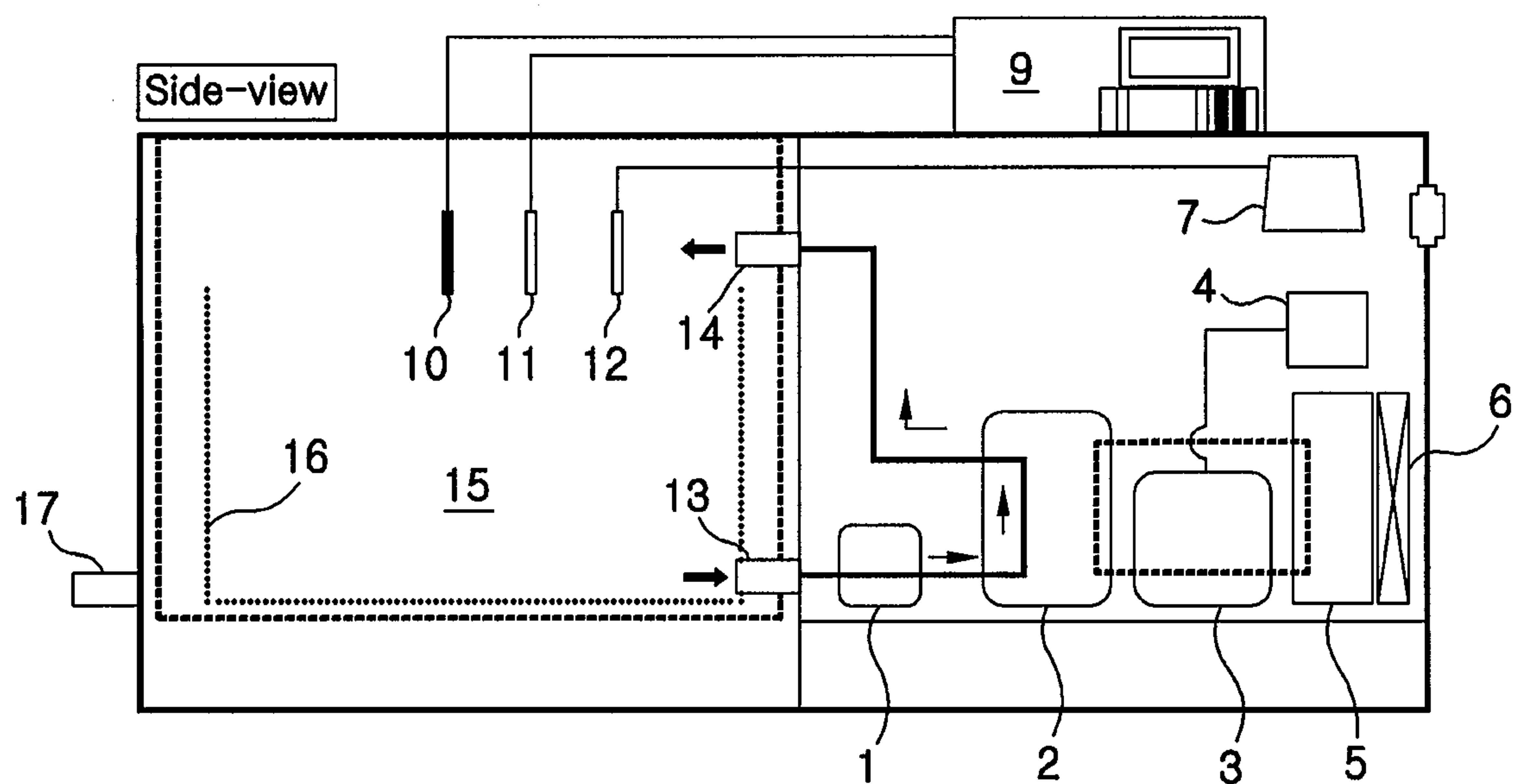
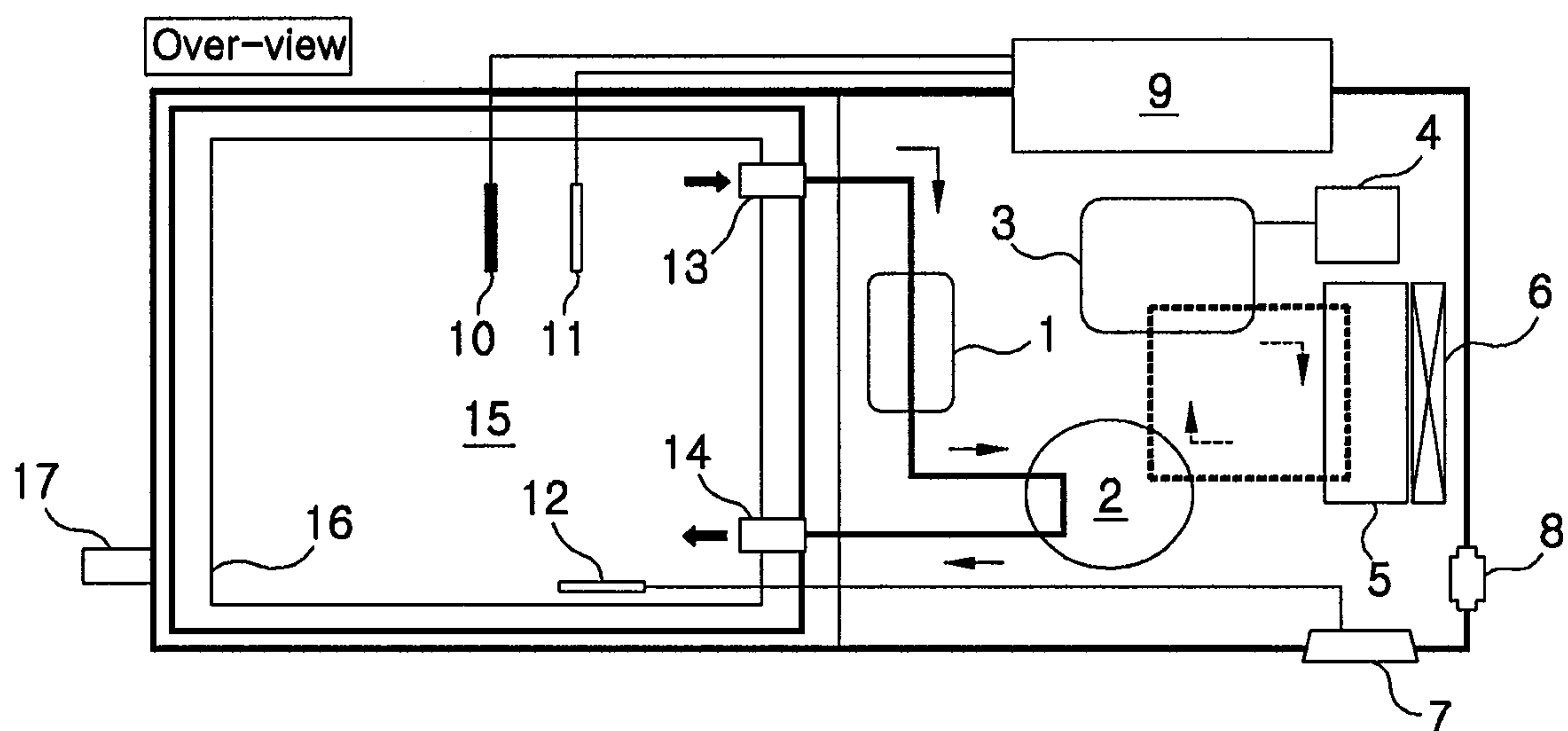
FIG. 8**FIG. 9**

FIG. 10**FIG. 11**

WATER TEMPERATURE (°C)	TIME (min)				TOTAL TIME CONSUMED
13	10				1185min (19h45m)
12		20			
11			30		
10				40	
9				50	
8			60		
7				80	
6				120	
5				180	
4				260	
3				180	
2				120	
1					20
C.S.					15