Mechanical Structure and Functions of Zootron (the Climatic Facility for Domestic Animals) in Tsukuba

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In order to investigate the relationship between changes of environmental conditions and physiological or productive responses in domestic animals, environmental factors must be simplified and controlled. For such a purpose, the first large climatic facility was built at the University of Missouri in U.S.A. in 1948[2]. In Japan, a small one was built at Tohoku University in Sendai in 1960 and then the first large scale climatic facility at the National Institute of Animal Industry was built in Chiba in 1976. In 1980 the National Institute of Animal Industry moved into Tsukuba and the climatic facility was renewed in the new institute area. The new facility, which is named Zootron[1], has about 1,500 m² of the floor area and some new equipments and systems are installed.

Space arrangement in Zootron

Zootron (Fig. 1) consists of seven insulated test rooms (from A to G, ca. 500 m²), two machine rooms (I and II, ca. 500 m²) and

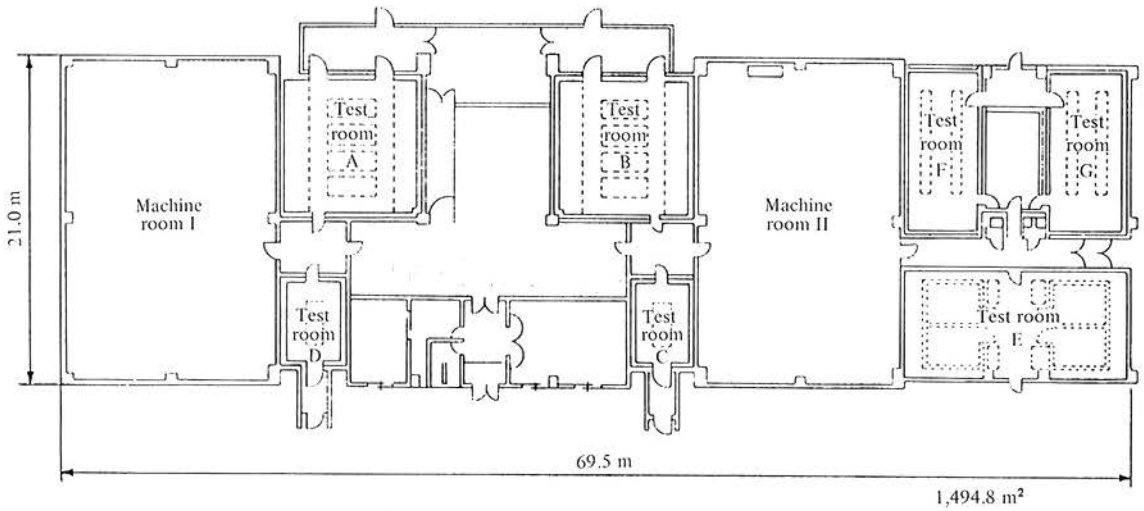

Fig. 1. Space arrangement in Zootron

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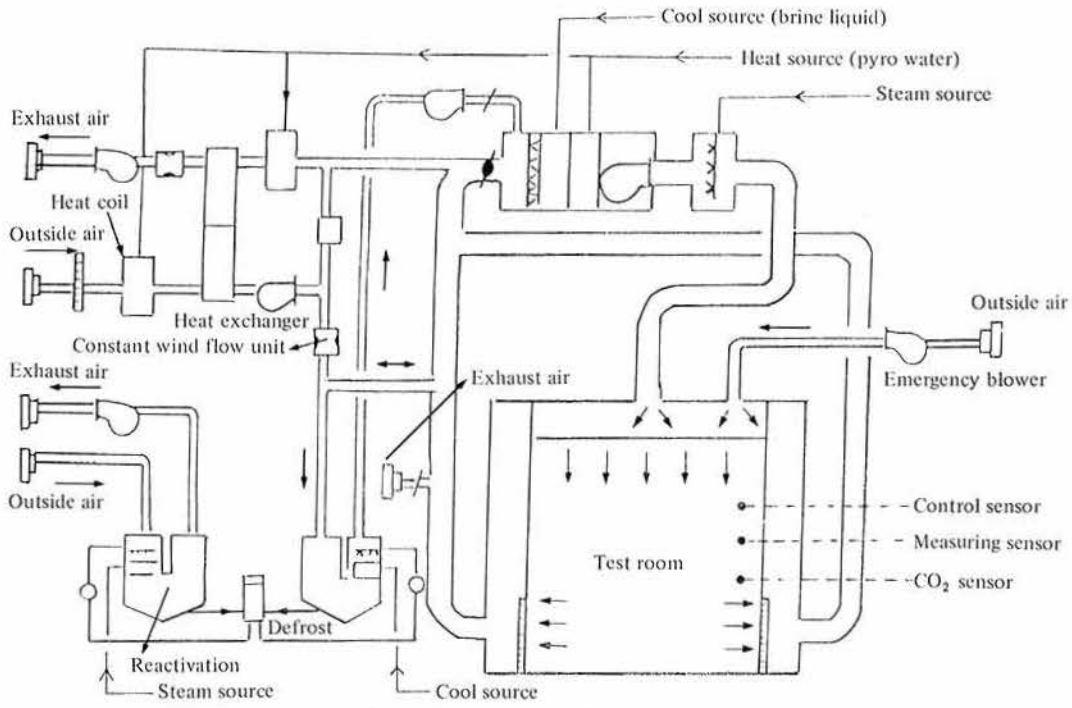

Fig. 2. Hygro-thermo controlling system of Zootron

work spaces (ca. 500 m²). The seven test rooms are divided into three groups according to the location in Zootron and to the experimental animals to be housed. The four test rooms from A to D are mainly used for the experiments with dairy cattle and other ruminants. We'll deal in this report with only these four test rooms for dairy cattle, because these test rooms occupy the central part of Zootron in installations and in energy cost, whereas the other three test rooms from E to G are used to house small experimental animals and laying hens.

Structure of the test rooms

The walls of the test rooms are plastered with the stainless steel boards. Those stainless steel boards avoid corroding from feces and follow well the air temperature in the test rooms. These stainless steel boards are plastered on the wood frames, which are constructed inner side of the reinforced concrete structures. The spaces between the concrete structures (outside walls) and those stainless steel boards (inside walls) are used for the pass way of the conditioned air from air conditioning equipments into the test rooms (Fig. 2).

Environmental conditioning system

The environmental conditioning system consists of air conditioning equipments and measuring equipments (Figs. 2 and 3). Fresh air comes into air conditioning equipments from the outside of Zootron. The temperature and humidity of this fresh air are conditioned in the air conditioning equipments as we set up. The conditioned fresh air is sent into the test rooms through the small holes on the ceiling (rooms A and B) or on a side wall (the other rooms). Flow speed of this fresh air is controlled to less than 0.5 m/sec. The air in the test rooms is pressed out by the fresh air through the air filters which are set in the side walls (test rooms A and B) or in the opposite walls of the air entrances

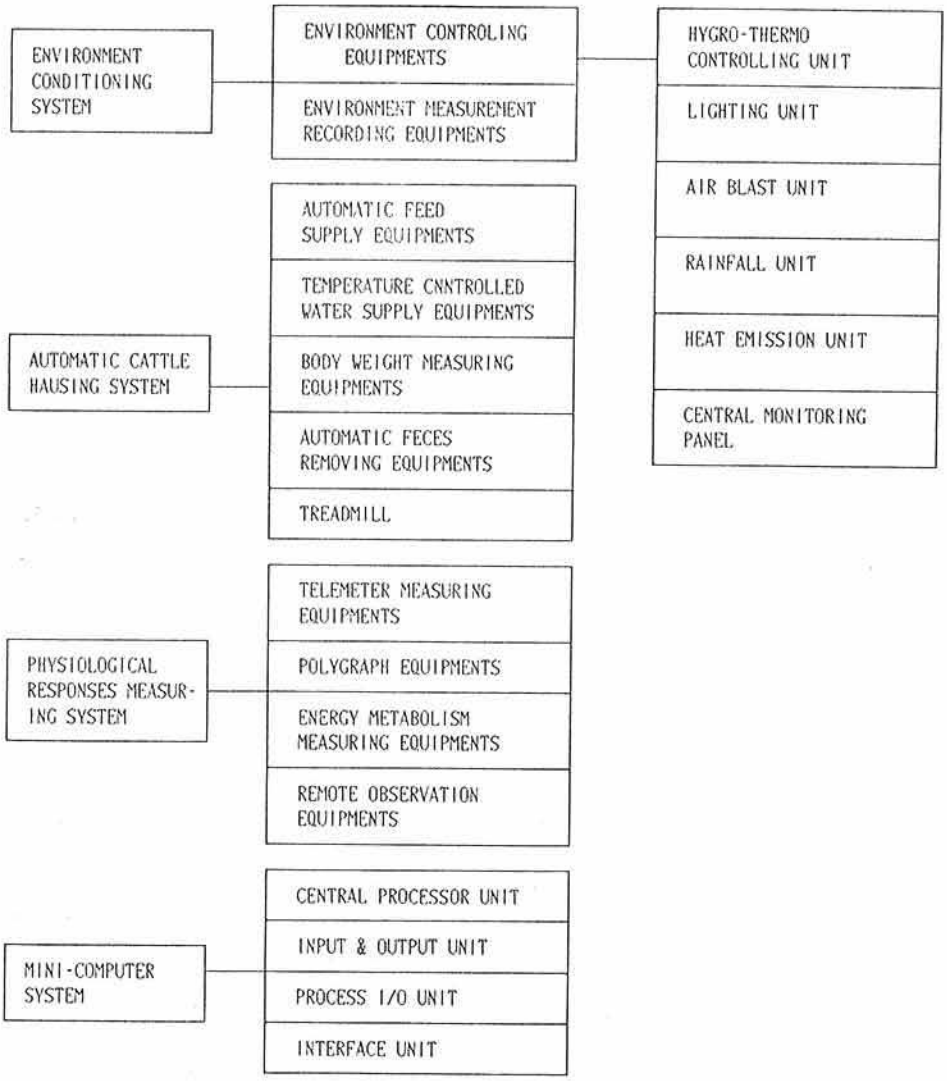

Fig. 3. Constitution of each system in Zootron

(the other test rooms). A part of this air from the test rooms is exhausted out of Zootron directly. But the most part of the air from the test rooms returns to the air conditioning equipments and is used again for circulation, in order to save the air-conditioning energy. As the heat source to warm up the air, high pressure (9 kg/cm^2) and high temperature (150°C) water is supplied from the energy center in the site of this institute. And to cool the air in the air conditioning equipments electric refrigerators are used.

The ranges of temperature and humidity which we can set in each test room are shown in Table 1. The air temperature and humidity in the test rooms are controlled by the self-regulation (feedback) system. The measuring equipments have the sensors in each test room. The air temperature in each test room is measured with the platinum-resistance-thermometers electrically. Control detectors of the measuring equipments in the control panel keep comparing the air temperture in the test rooms with the set up temperature always. The control detectors send out the electrical signals in voltage according to the difference

Table 1. Functions of each test room

Test room	A, B	C	D
Room space (Wm×Lm×Hm)	8.6×5.5×3	5×3.5×3	5×3.5×3
Controlled range of temperature (℃)	−15—+45	−25—+45	−25—+45
Controlled range of humidity (%)	30—85	30—85	30—85
Light intensity (lx)	0—500	0—500	0—500
Wind velocity (m/sec)	0.5—2.5	—	—
Rain strength Temp. of rain	—	15—50mm/hr 5—35℃	—
Radiation ($cal/cm^2 \cdot min$)	—	—	0—0.5
Treadmill (m/min)	—	—	0—120
Number of housing cattle	4 heads	1 head	1 head

between the actual air temperature in the test room and the set up temperature. The fresh air from the outside of Zootron and the recycled air from the test rooms are warmed or cooled in the air conditioning equipments following the electrical signals which are sent from the control detectors. The air temperature in the test rooms is controlled within the range of ±0.5°C of the set up temperature. The maximum increase or decrease rate of the temperature in the test rooms is 10°C/hr, when the set up temperature is between 5°C and 40°C and the air temperature outside Zootron is in the range of 5–25°C.

The relative humidity is calculated with the temperature of dry bulb (air temperature) and that of wet bulb. When we set up the humidity in percent, the control system calculates the wet bulb temperature corresponding to that humidity (%), and compares it with the actual wet bulb temperature in the test room. When the wet bulb temperature in the test room is higher or lower than the calculated one, the control detector generates electric signal, by which the air in the conditioning equipment is dehumidified or humidified. The humidity in the test rooms can be controlled in the range of 30–85%, at the air temperature higher than 10°C.

Special installations

There are some special installations in each test room. In order to investigate the effects of wind on cattle under various environmental conditions, wind-equipments are installed in the test rooms A and B. Each wind-equipment consists of a wind duct and two wind fans. Each wind duct has the mouths in front and in the rear of the stanchion stall. The wind duct is partly separated into two pathways and in each pathway the wind fans are installed inversely each other. We can select the wind direction by switching on and off these fans. We can set up wind-velocity between 0–2.5 m/sec.

The test room C has artificial rainfall equipment. There are two pipes with four nozzles for the artificial-rainfall under the ceiling in the test room. The one pipe is used for low rainfall intensity (15–25 mm/hr) and the other pipe for high intensity (25–50 mm/hr). This equipment consists of two water pumps and a water tank. The rainfall intensity and the rain temperature can be adjusted in the

range of 15–50 mm/hr, and 5–35°C respectively.

In order to investigate the effects of out door exercise under the sunshine on the cardio-respiratory system in cattle, a treadmill and the infrared radiation-equipment are installed in the test room D. The speed of the treadmill is controlled between 0 and 120 m/min. The infrared radiation-equipment, which consists of 18 reflection-lamps, is hanging from the ceiling over the treadmill. The reflection-lamps are covered with black bonnets and the infrared light from the lamp comes through the blacked glass filter only to the floor direction. Intensity of the infrared radiation can be adjusted to 9 grades from 0 to 0.5 cal./cm^2/min by the on-off switching of the lamp.

Automatic cattle housing system

It is difficult to keep cattle in a test room for a long term, because temperature and humidity in the test room are often too high or too low for the cattle raising worker. Therefore, we planned to reduce worker labor. For such purpose, some installations, such as automatic feeding, water-supplying and feces-removal installations, are provided.

With the automatic feeding equipments provided to the test rooms A and B, we can set up the feeding times (max. 6 times in a day), the feed-sorts (max. 3 sorts) and the feed-weight (from 0.1 to 20.0 kg) for each cattle.

Each water-supplying equipment has a water-cup in front of each stall and a couple of water tanks. These tanks are connected each other and a circulation pump is set between them. The large tank is placed on the ceiling and another small one surrounds the water-cup on the floor in the test rooms. Drinking water temperature is controlled in the large tank and the water is circulated between these two tanks by the circulation pump. The water-cup is covered with the small tank, so that the temperature of the drinking-water in the water-cup is kept at the same temperature of the water in the tanks.

Feces are removed by high pressured water from Zootron. We can set the time of water flush.

Mini-computer system

The most important system of new Zootron is the mini-computer system. This system supervises the whole systems. Namely, if we make an experiment once with the cattle, it continues for more than 40 days generally, so that a large amount of environmental, physiological and feeding data are brought out from time to time. Therefore, we must always keep paying attention to the flood of data and to the condition of experimental cattle. It is difficult for us to continue such a strain for a long period. In order to solve the problem, we thought out a linkage of data-sources and data disposition. As the operating system (one of the important soft-wares), MRDOS (Mapped Real Time Disk Operating System) is adopted. Fig. 4 shows the outline of the hard-wares of the mini-computer system. The computer gathers environmental data, such as air temperature, humidity and light-intensity in the test rooms every 3 minutes. Water consumption and some physiological data in each cattle in the test rooms, such as heart rate, respiration rate and body temperature can be registered in the computer every 3 minutes, too. Productive and feeding data, such as milk-yield, feed consumption and body weight in every cattle can be sent into the computer with the manual switching. This computer system is used not only to gather the data, but also to calculate the data which we input after the experiments.

Security system

In order to carry out experiments for a long term without accident, Zootron has a security system. The security system detects disorders not only of the total air conditioning mechanisms, but also of environmental conditions in the test rooms. There are many detectors and sensors in the environment conditioning equipments and in the test rooms.

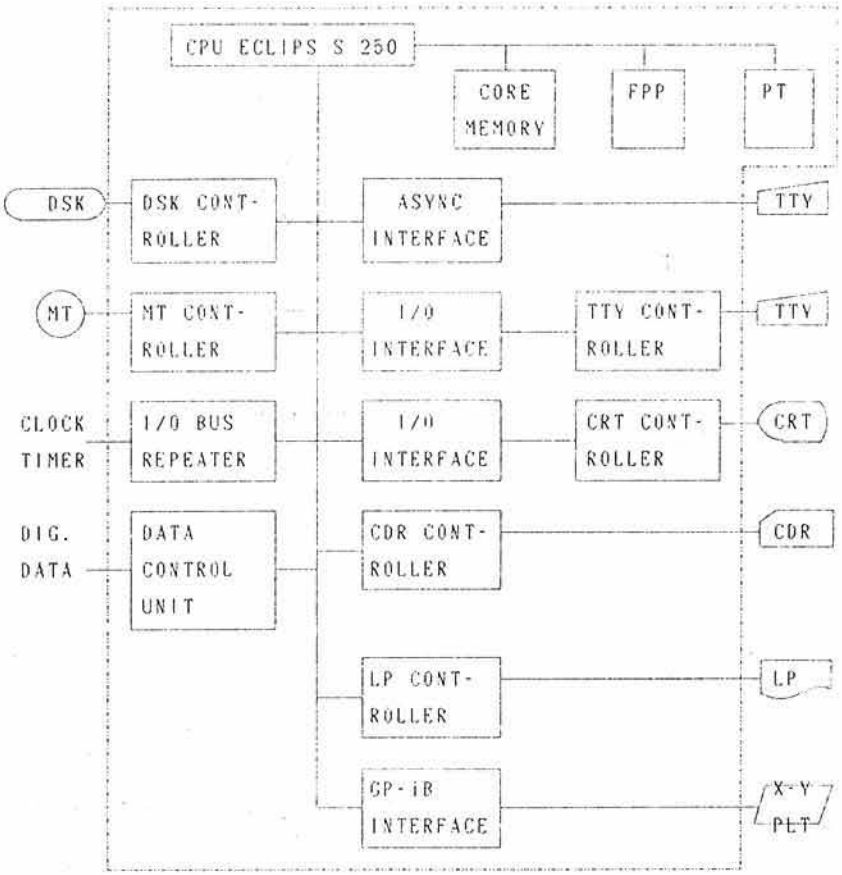

Fig. 4. Diagram of the mini-computer system

The detectors find the mechanical and electrical disorders of the machines and the security system shows us the point of disorder with light and sound. There are a thermometer and a CO_2-sensor as an end of the security system in each test room. And if the room temperature becomes 2°C higher or lower than the levels which we set up, the security system alarms us with light and sound. If the air temperature in the test rooms is over the limited temperature which we can set up between 20–50°C (high limit) and between −30–0°C (low limit) or if the CO_2 concentration exceeds the limited value which we can set up between 0.1–1.0% too, the security system decides that a serious emergency occurred. In such a case, the experiment is compulsively interrupted, and to rescue experimental animals, a large amount of fresh air is introduced into the test room.

Physiological responses measuring system

The measuring system consists of four gas analyzers, four poly-graphic (total 32 channels) and 12 telemetric devices (total 36 channels). Through this system the level of energy metabolism and some physiological responses, such as electro-cardiogram, electro-encephalogram and so on, are measured and recorded.

Some experimental results

Since 1981 Zootron has been used to investigate "Relationship between Milk Yield and Thermal Environment in Holstein Dairy

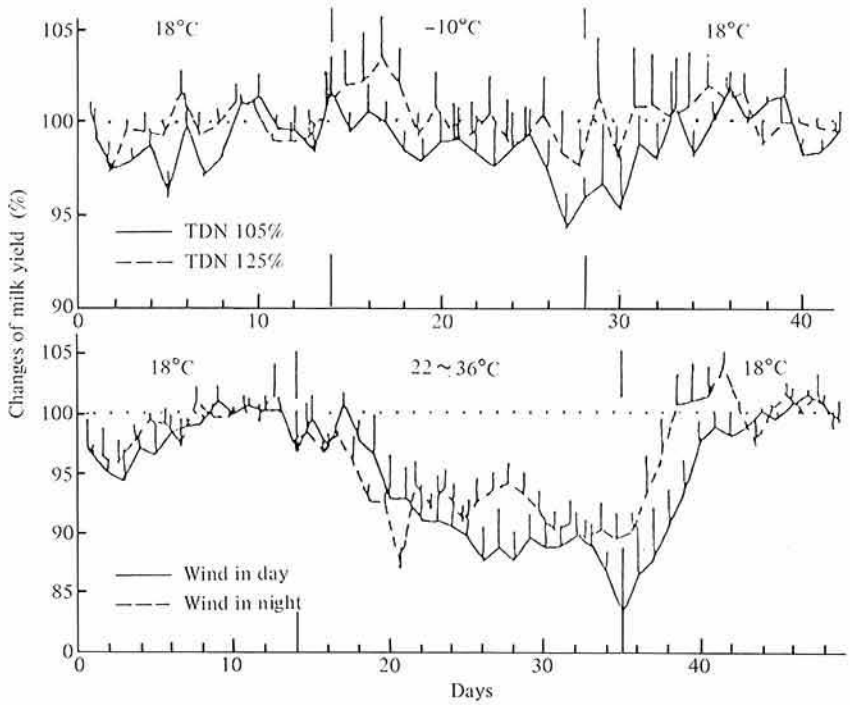

Fig. 5. Changes of milk yields in cold and hot environments

Cattle". Milk yield in Holstein dairy cattle is influenced by environmental temperature, especially in a hot environment. Therefore, to reduce the influence of heat stress on the dairy cattle, farmers operate wind-fans to the full extent in the stall in the daytime in hot summer, but they stop operating the wind-fans to save the running cost of the wind-fans when it becomes a little cooler in the evening. Fig. 5 (lower chart) shows the effect of wind on the milk yield in a hot environment. We set up the air temperature at 36°C in daytime and at 22°C in nighttime in the test rooms A and B. The wind-fans in the test room A were operated in daytime (12 hr), while those in the test room B were run in nighttime (12 hr). This experiment explains that the wind in cool time is more economical than that in hot time. Milk yield in dairy cattle decreases not only under the hot environment, but also under the cold environmental conditions. Fig. 5 (upper chart) shows changes of the milk yield due to the cold conditions. If the temperature decreases lower than −10°C and we want to maintain the level of milk yield, dairy cattle must be given the feed about 20% more than that under the mild conditions. Such critical temperature at which we must give more feed, lies between −5° and −10°C.

Zootron will be used for more multifarious purposes, because various environmental conditions can be made in Zootron as mentioned above.

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