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AN EXPERIMENTAL STUDY OF
THE RELATIVE CONDUCTIVITY OF
VARIOUS BUILDING MATERIALS

THESIS FOR THE DEGREE OF B. S.
J. S. McCollough
1934

THESIS

**An Experimental Study of the Relative Conductivity
of Various Building Materials**

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This thesis is one that originated while considering the heat insulating properties of different building materials. There are a number of different building materials that are now available for wall covering, sheeting, lathing, etc., in home building. There is but little variation in cost but there is a wide variation in the value of these different materials in construction processes when one takes into account the ease of heating a home in winter and the degree of coolness in summer. One of the important factors in these two considerations is that of heat transfer.

Heat energy is transferred by three different methods; namely, conduction, convection and radiation. Conduction is the method by which heat energy is transferred from molecule to molecule in a material substance. It is a matter of common observation that different molecules do not conduct heat with equal ease and it is the purpose of this experiment to determine which of the various insulating materials now on the market have the lowest heat conductivity.

Samples of insulating materials were obtained from five manufacturers of representative types in common use. In each case the sample used was approximately eighteen inches square and of thickness and density equivalent to the stock with which the manufacturer is furnishing the building field. The materials tested were; Insulite, Celotex, Balsom Wool, Cork Board, and Nu Wood.

The apparatus used in the experiment consists of a white pine heating box the interior surfaces of which are lined

with asbestos paper. Its dimensions are 11" x 11" x 22" figure - 13. This box is cut in two at its mid-point, the cut edges of these two halves being lined with felt to make possible a more perfect bond between the boxes. The bottom half is placed upon a suitable base so that an electric light socket may be inserted through the bottom of the box. Through the top of the other half an accurately tested thermometer is inserted and held securely in place by a rubber stopper. One of the specimens of building material to be tested is placed between the lower and upper parts of the box forming a partition between the lower heating space and the upper heat registering space. Five such boxes were used so that five different materials could be tested at the same time. Five 100 watt mazda type 'C' lamps were used as the source of heat and have been standardized for like conditions of current and voltage.

The experiment was performed in the cold storage room of the Horticulture Department. This room is thermostatically controlled to remain at a temperature not varying more than two degrees Centigrade above freezing. After the boxes with the materials to be tested were mounted in place they were left stand in the room until they all approached approximately zero degrees Centigrade. Then all the thermometers were read, the readings recorded, and the current turned on. The temperature of the upper boxes, as indicated by the thermometers, was then read and recorded at five minute intervals until there was no further increase. At this point the radiation of

the surfaces of the upper boxes was just equal to the amount that was being conducted through the partition by the insulating material. After each 'run' the boxes were dismounted and allowed to cool off again to the near freezing temperature. Each material that had been tested was then put in a different box than the one in which it had been tested the preceeding time and put through another 'run'. In this way the five materials were tested five times, once in each box, by a series of five runs. By testing each material in every box they were all given identical conditions for comparison because all runs were made at the same room temperature. It also eliminated any danger of differences in the properties of the heating boxes, all materials being equally exposed to the good or bad conditions offered in each box. The average time for a run was about six hours. However, the different materials reached a point of equilibrium between the heat entering by conduction through the insulation and that escaping by radiation from the surface of the boxes at different times, depending upon the conducting properties of the material.

After the first series of tests were run and the readings recorded, instead of working out the absolute thermal conductivity of the substances, the results were plotted graphically upon coordinate paper. First, graphs were plotted showing the readings of a particular building material under the conditions represented by each of the boxes. (figures - 1 - 2 - 3 - 4 - 5) The average rise of the five boxes for each material was computed and these values represented by M

(mean value) are the ones connected by the curve. It is interesting to note that in every case when the material was tested in box 5 the curve falls off at a faster rate than do those representing the other boxes. This noticeable difference is no doubt due to a weakness in the construction of the box. The heating sources of all the boxes were tested before and after the experiment and there is no appreciable difference in the wattage consumption among the five lamps.

When the mean values of each of the materials were plotted for comparison (figure - 11) it was discovered that the curves representing them crossed and recrossed each other. For example; the curve representing Balsam Wall starts with a decided steeper curve than do the other curves. However, after the test has continued for several hours this curve begins to fall off and it declines until it crosses the curves representing Nu Wood and Celatex. In a similar manner the curve representing Cork first crosses the Insulite curve after about fifteen minutes have elapsed and then after two hours time begins to rise more rapidly than the other curve and recrosses it again. It was thought that it must be some peculiarity inherent in the material that caused these non-uniform changes. However, when the graphs representing the characteristics of each of the boxes with a single material were investigated more closely it was found that they also crossed in the same way. This similarity in the curves of the boxes with those of the materials led to the conclusion that it must be a fault of some ^{part} ~~part~~ of the apparatus that was

causing the condition. A second series of tests was therefore planned for the purpose of seeing if it were possible to eliminate or explain the reason for such crossings of the curves.

The first explanation considered was that the variance was caused by a changing power supply to the bulbs. To ascertain if the supply were changing an amount great enough to cause the difficulty a wattmeter was installed in the circuit with the lamps. In addition, to counteract the losses due to radiation from the bottom box it was insulated on the bottom and sides with half an inch thickness of Insulite. There seemed a possibility too that the material might tend to warp in the damp room after being heated, thus causing a loss of heat at the junction of the two halves of the box with the material being tested. To prevent such warping, four twenty-kilogram weights were placed on the top of each of the boxes.

The test, with the exception of these changes, was than repeated in exactly the same manner as the first one had been run. The readings taken from the wattmeter at the same interval as the temperature changes were of little help in solving the problem. While the wattage varied in extreme cases from 410 to 460 watts it was constant enough to make certain that the wattage was not causing the crosses. However, slight humps and dips in all of the curves may be due to a prolonged extreme, either high or low, in the power the lamps were using.

The data in the second series after being plotted proved to be much more regular than the first series. The graphs

showing the readings of particular building materials when tested in the different insulated boxes (figures - 6 - 7 - 8 - 9 - 10) have no noticeable crossings in comparison to those apparent in the curves drawn for the uninsulated boxes (figures - 1 - 2 - 3 - 4 - 5). Still more enlightening are those curves representing the mean values of the materials when tested in the insulated heating boxes (figure - 12). These curves show no trace whatever of the crossings.

The most logical conclusion would seem to be that the crossings occurring in the uninsulated box were caused by losses through variable radiation from the bottom half of the box. As the temperature increased so did the radiation from the box increase and different boxes having different properties of radiation were caused to heat and cool at different rates. The varying rates of heat radiation through the boxes making corresponding changes in the rate of conduction through the materials being tested.

Insulating the bottom box also made possible a higher range in temperature for the run. The median curves of figure - 12 being at least five degrees higher at their peak than are those curves for the same materials in figure - 11. The insulation around the bottom box prevented much of its former heat loss and a resulting higher temperature was obtained inside the box. Also, both series of tests did not take the same duration of time to reach their peak. The uninsulated box had no further increase in temperature after four hours had elapsed. The series with the insulated boxes con-

tinued to climb until they had nearly reached the end of the six hour period. Both series were carried out for the full six hours so that comparisons could be more favorably made by the graphs.

The kinks in the curves of the uninsulated series are due to a sudden change in temperature in the storage room. After the curves had flattened out the heat being conducted through the insulating material was just balanced by that lost through radiation from the upper box. The storage room was gradually warming as the test was run, and when it reached the temperature at which the thermostat operated the cooling system it was suddenly cooled off. The rapidly cooling room made possible a greater loss of heat from the boxes than was being admitted into them by the insulating materials. The increased heat loss was recorded by the dropping temperature. When the loss again became equal to the gain the curves once more leveled out.

In a comparison of the conducting properties of the materials tested both series point toward the same results. Cork is evidently the best insulator and is followed closely by Insulite. The other three materials are somewhat poorer and more closely allied. In one case Celatex is the better of the three and in the other Balsam Wool is best. Nu Wood apparently is the poorest of the group.

In my opinion the tests are a fair criterion of the insulating values of the materials. Pains were taken in every possible way to make certain that all materials were tested under

identical conditions. The only source for criticism may lie in the fact that four of the materials were of the board insulation type while the fifth, Balsam Wool is made from wood fibers in fleecy wool form. No doubt the dampness of the storage room, a nearly saturated condition, had more effect upon the Wool than the more dense insulators that were compared with it. The density of the Balsam Wool in pounds per cubic foot is only 3.62 while the density of the other materials varies from 10.0 for Corkboard to 16 for Celotex. Saturation of the Wool, which is 92 percent air space, may account for its rather poor showing in this test. However, the relative positions of the conductivities of the other materials compares favorably with values based on results from hot plate test methods run by the Bureau of Standards.

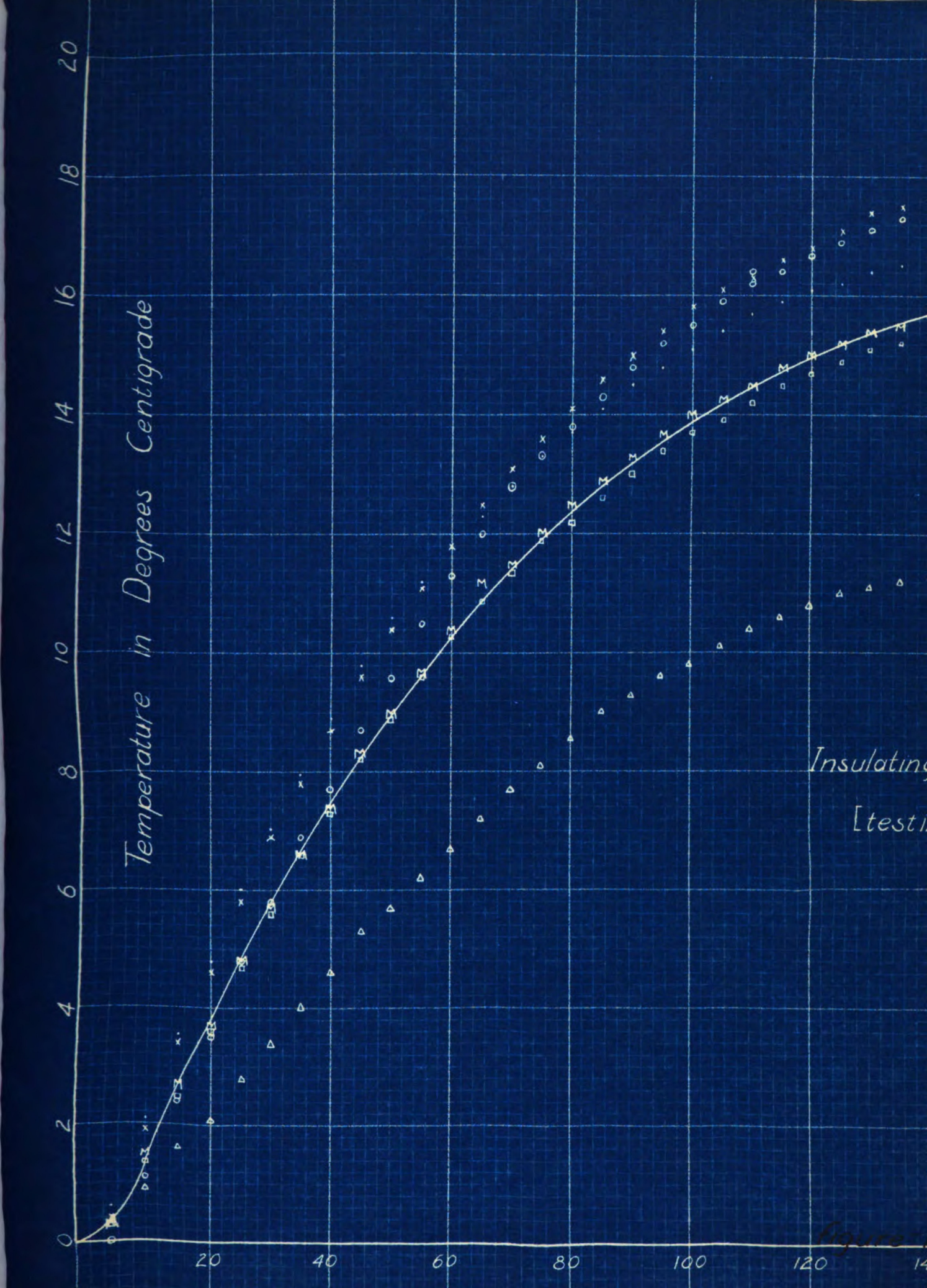
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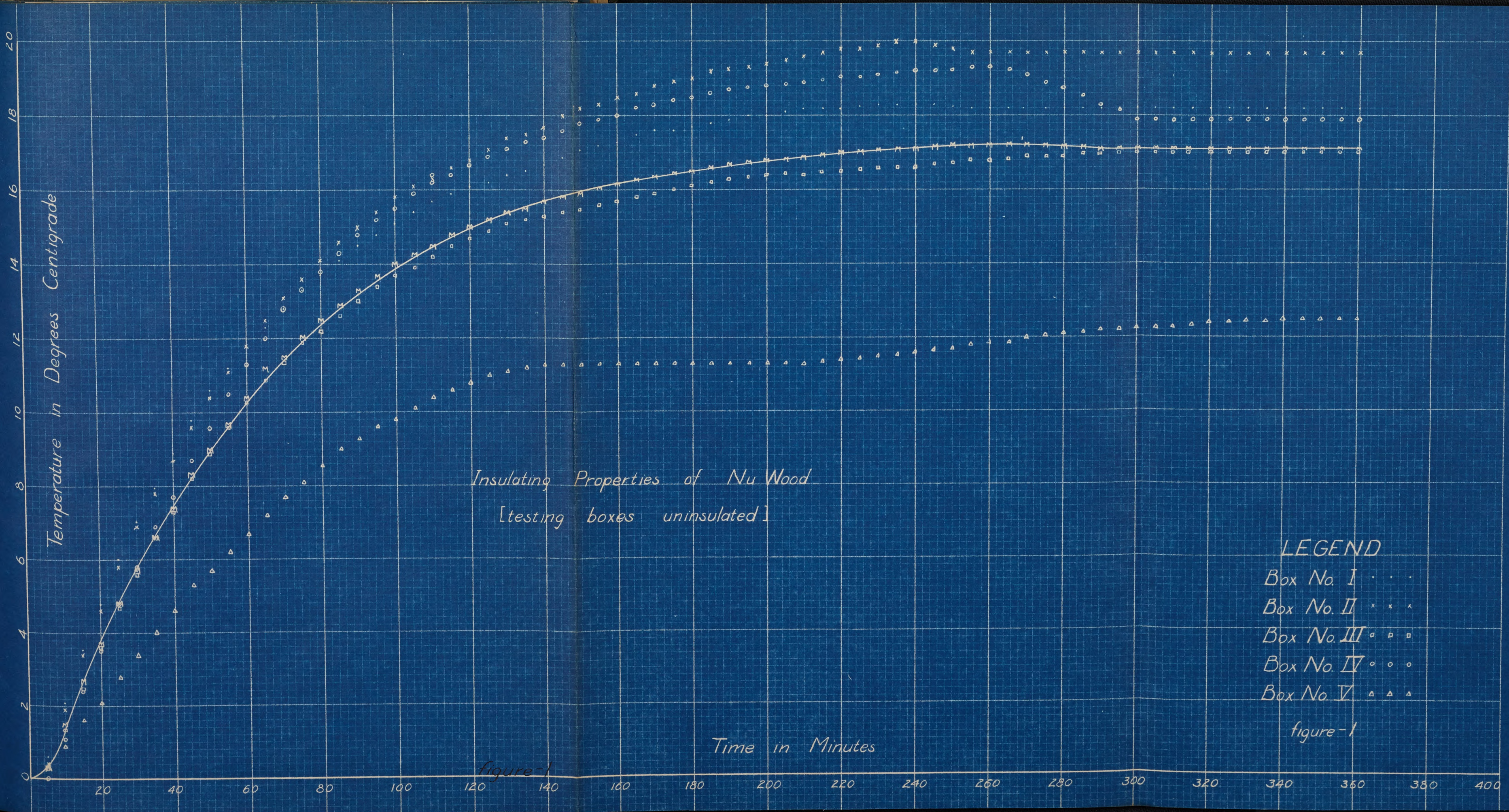
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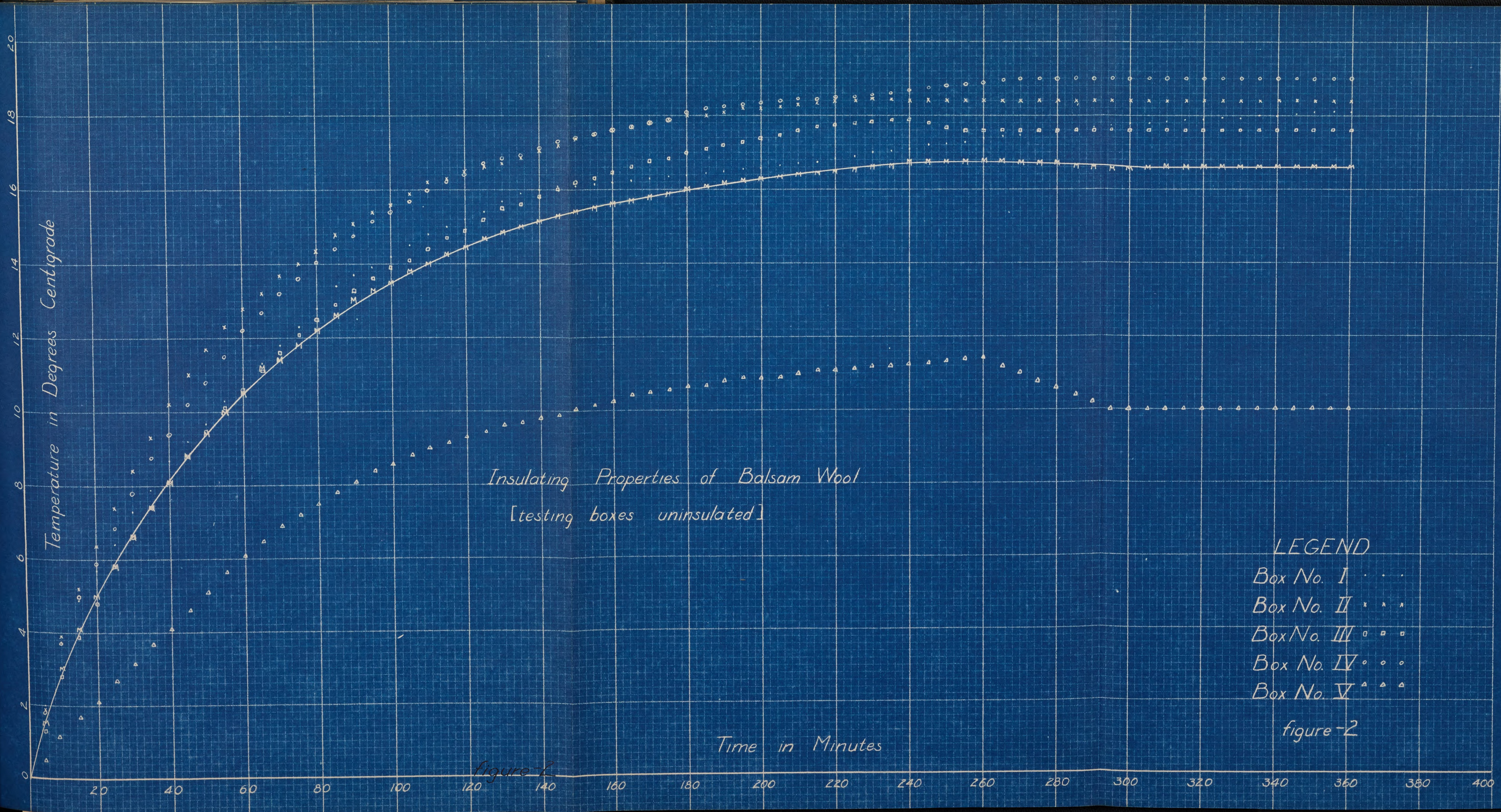
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Insulating
[test]

Figure 1







Temperature in Degrees Centigrade

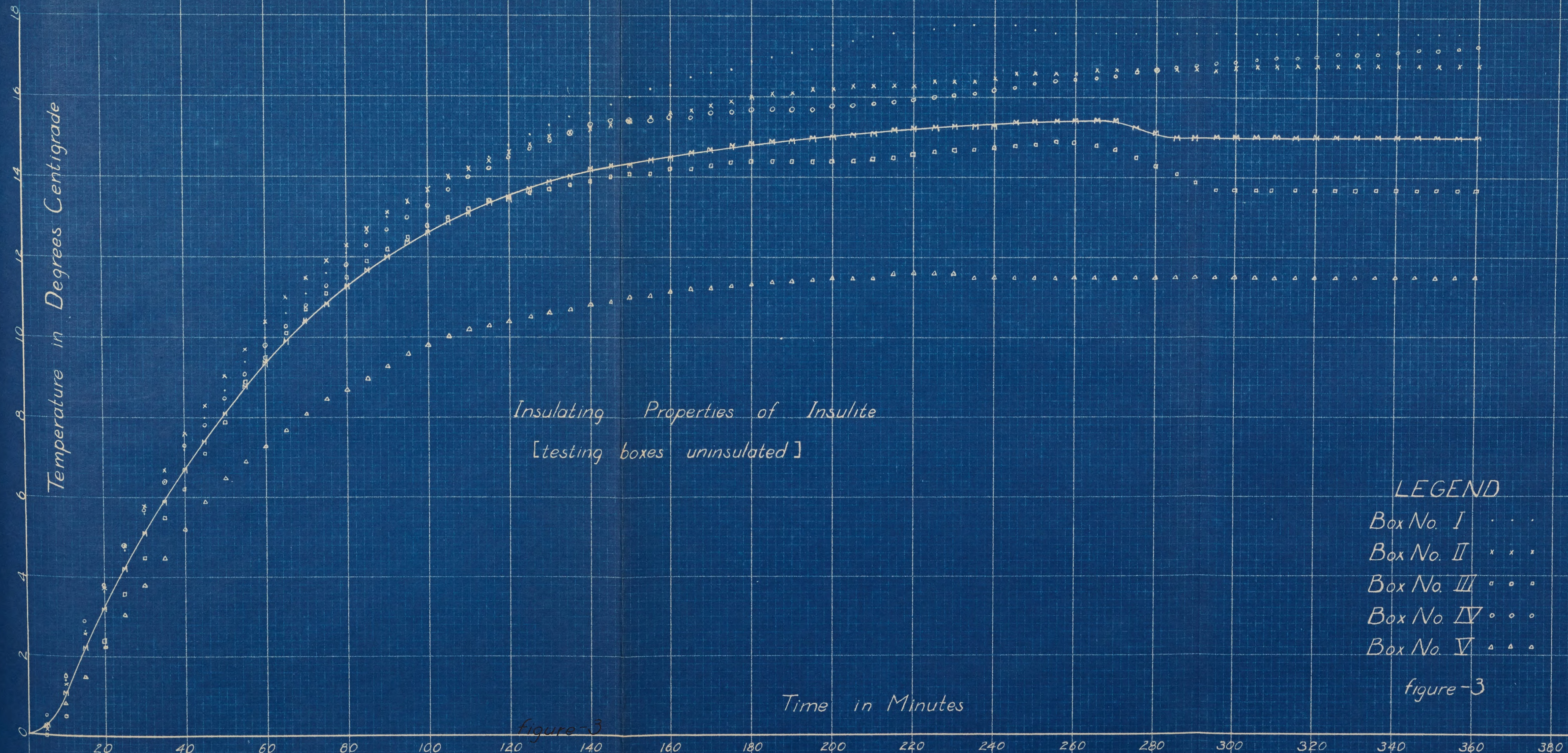
Insulating Properties of Balsam Wool
[testing boxes uninsulated]

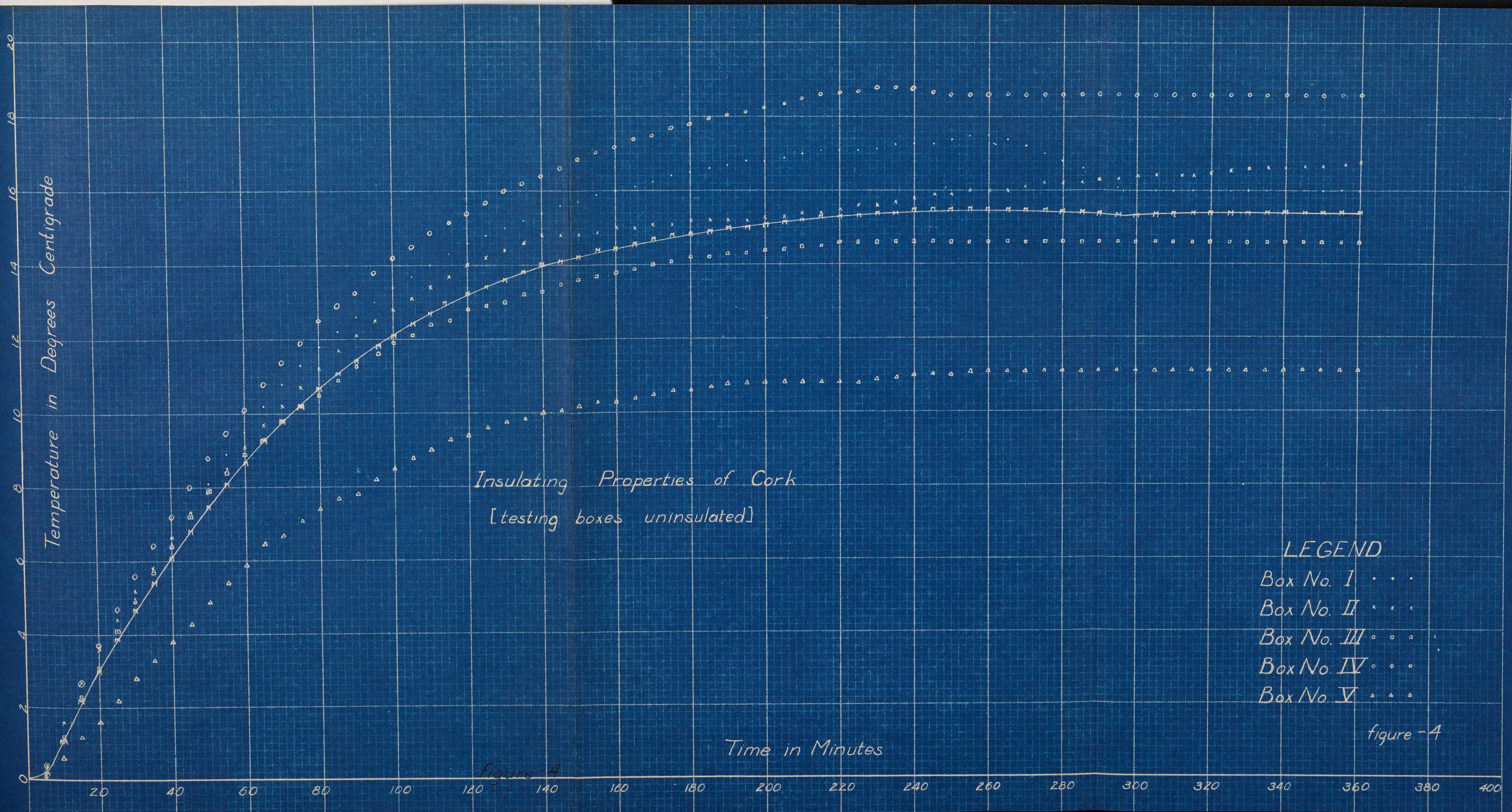
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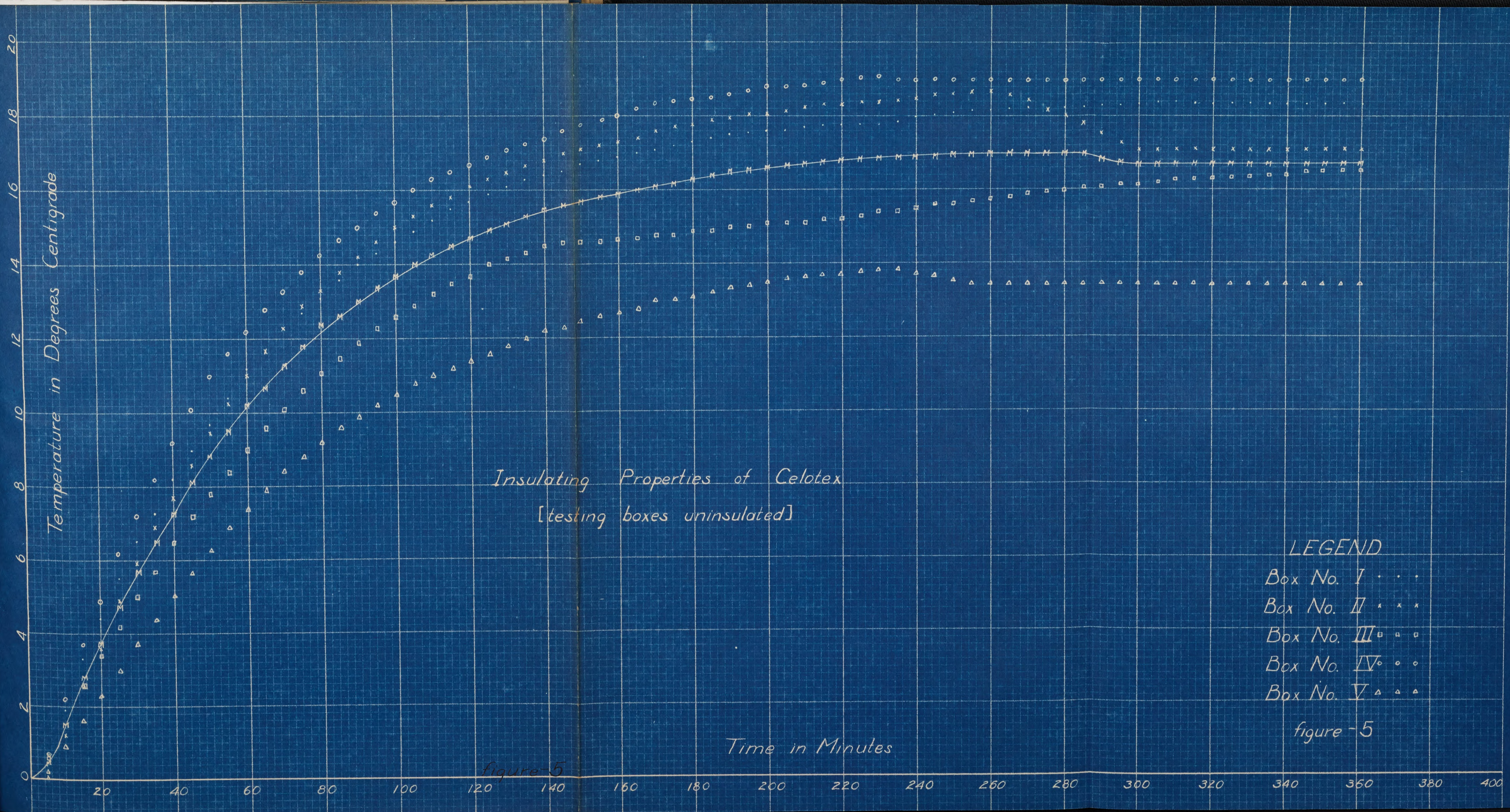
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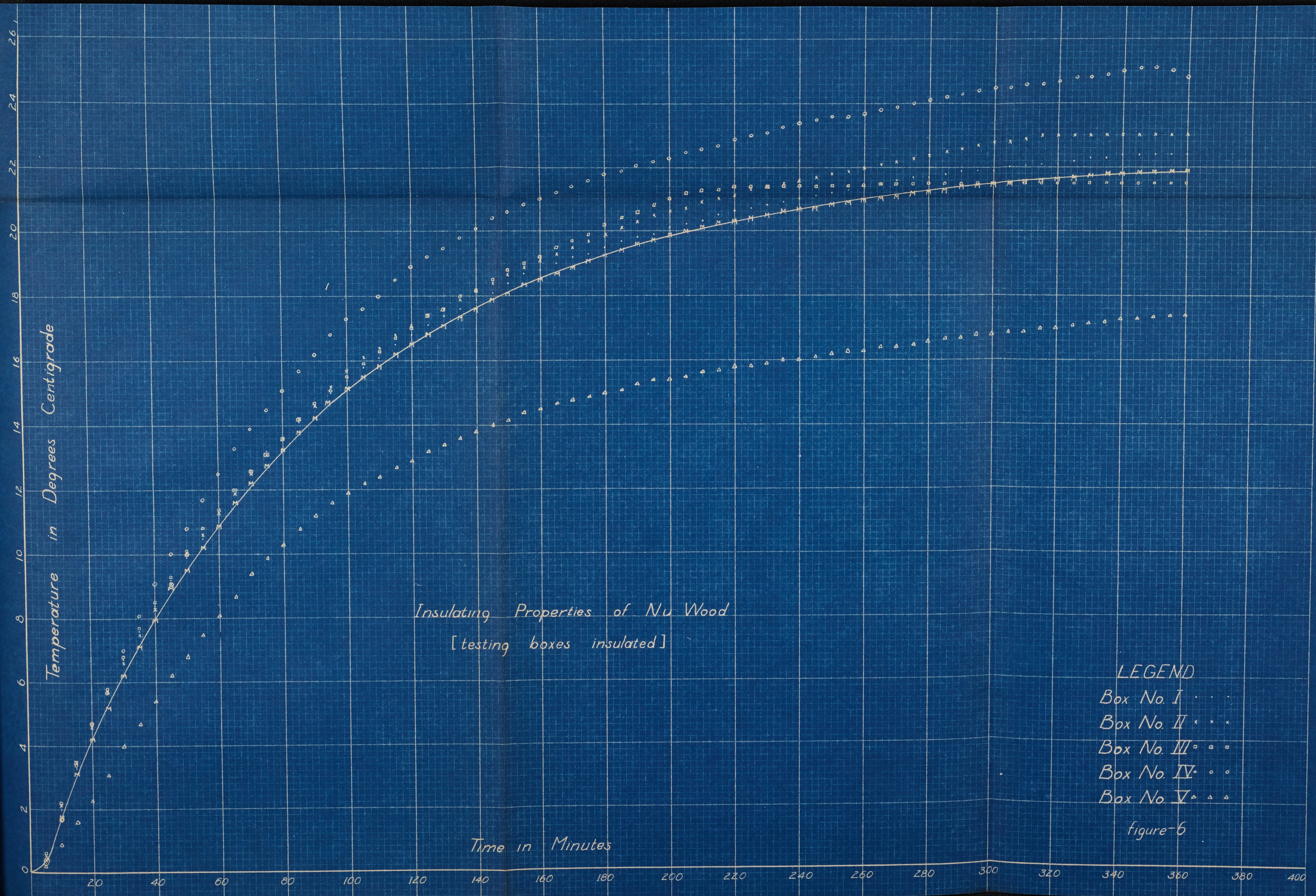
figure-2

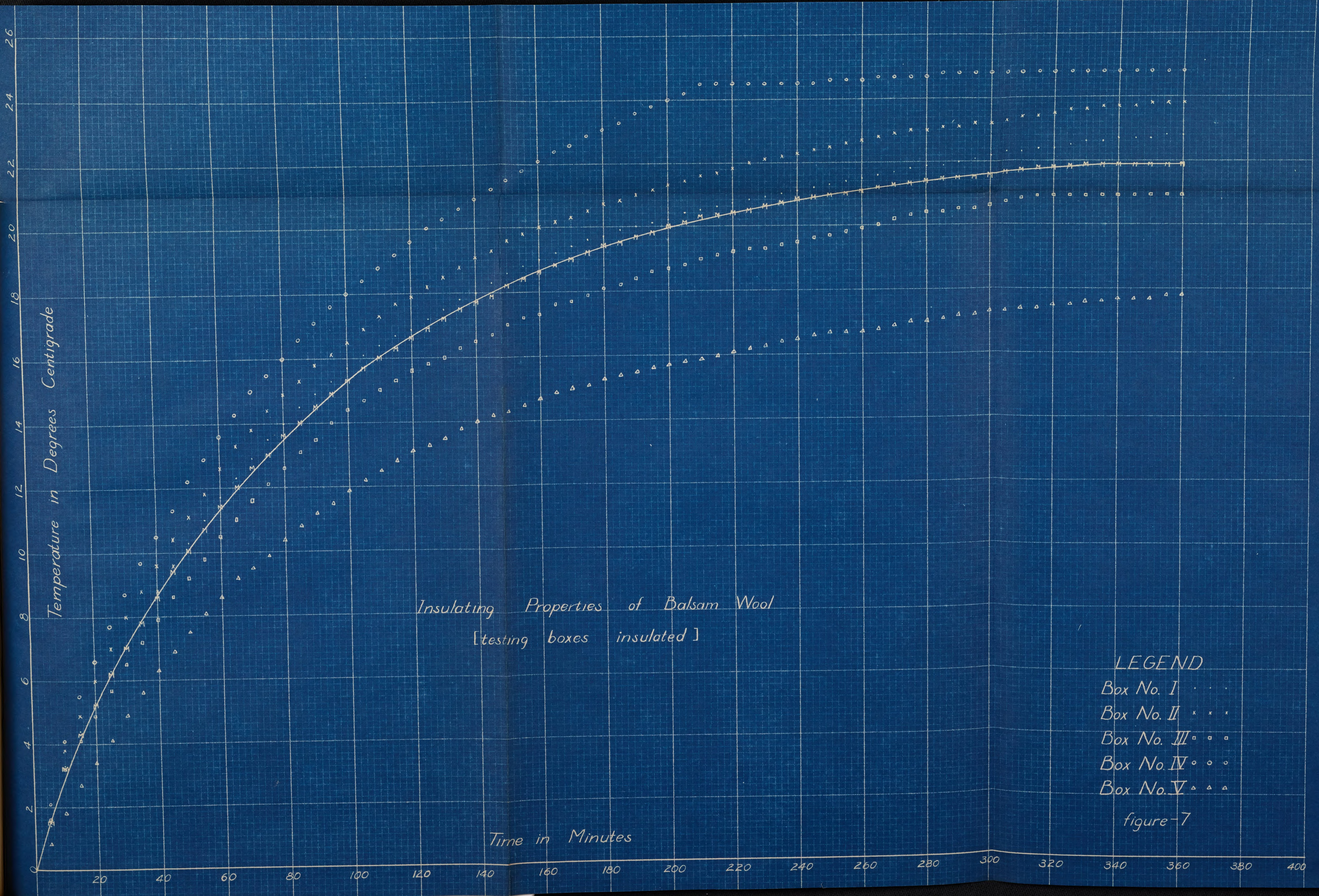
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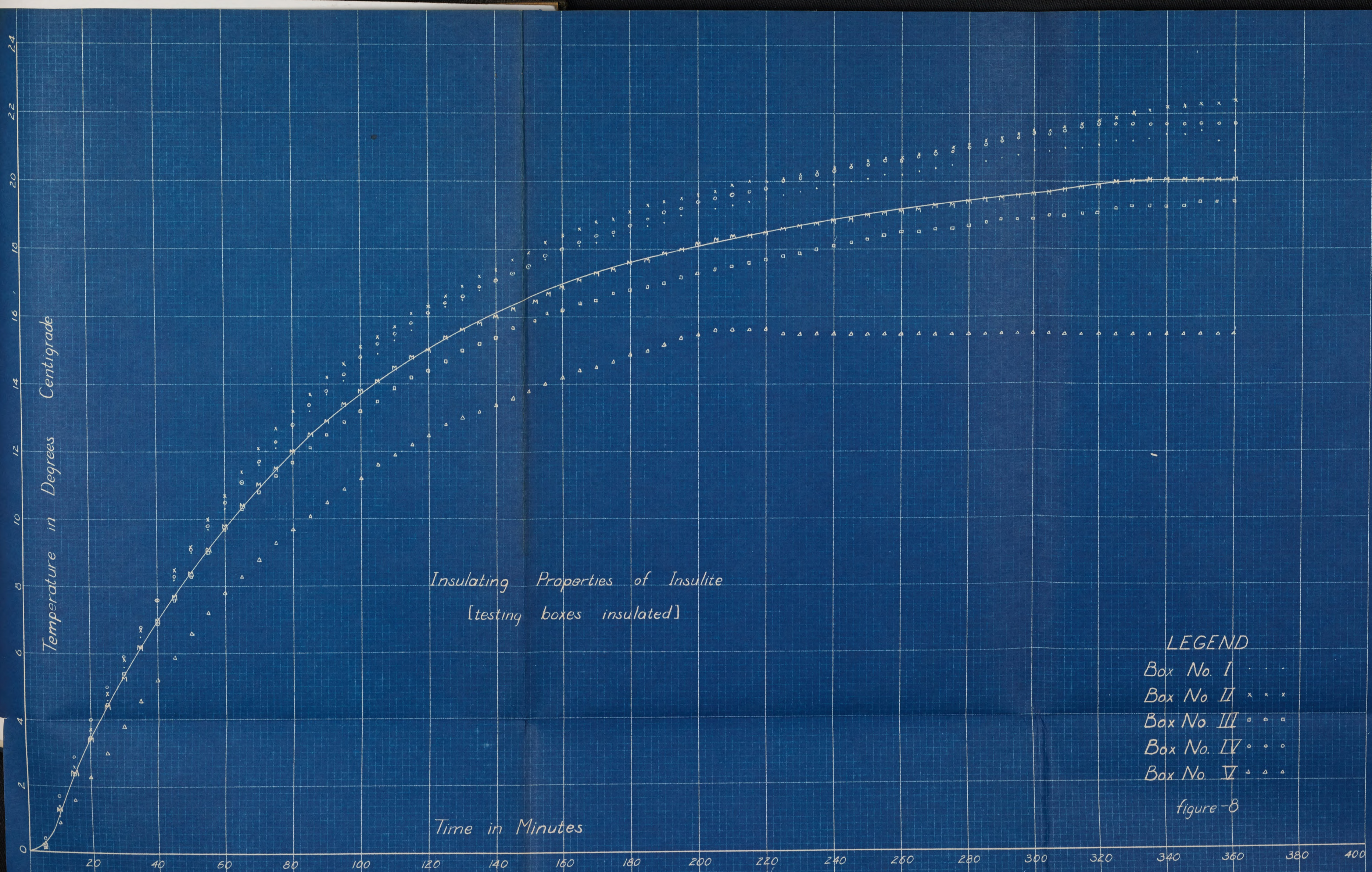












Temperature in Degrees Centigrade

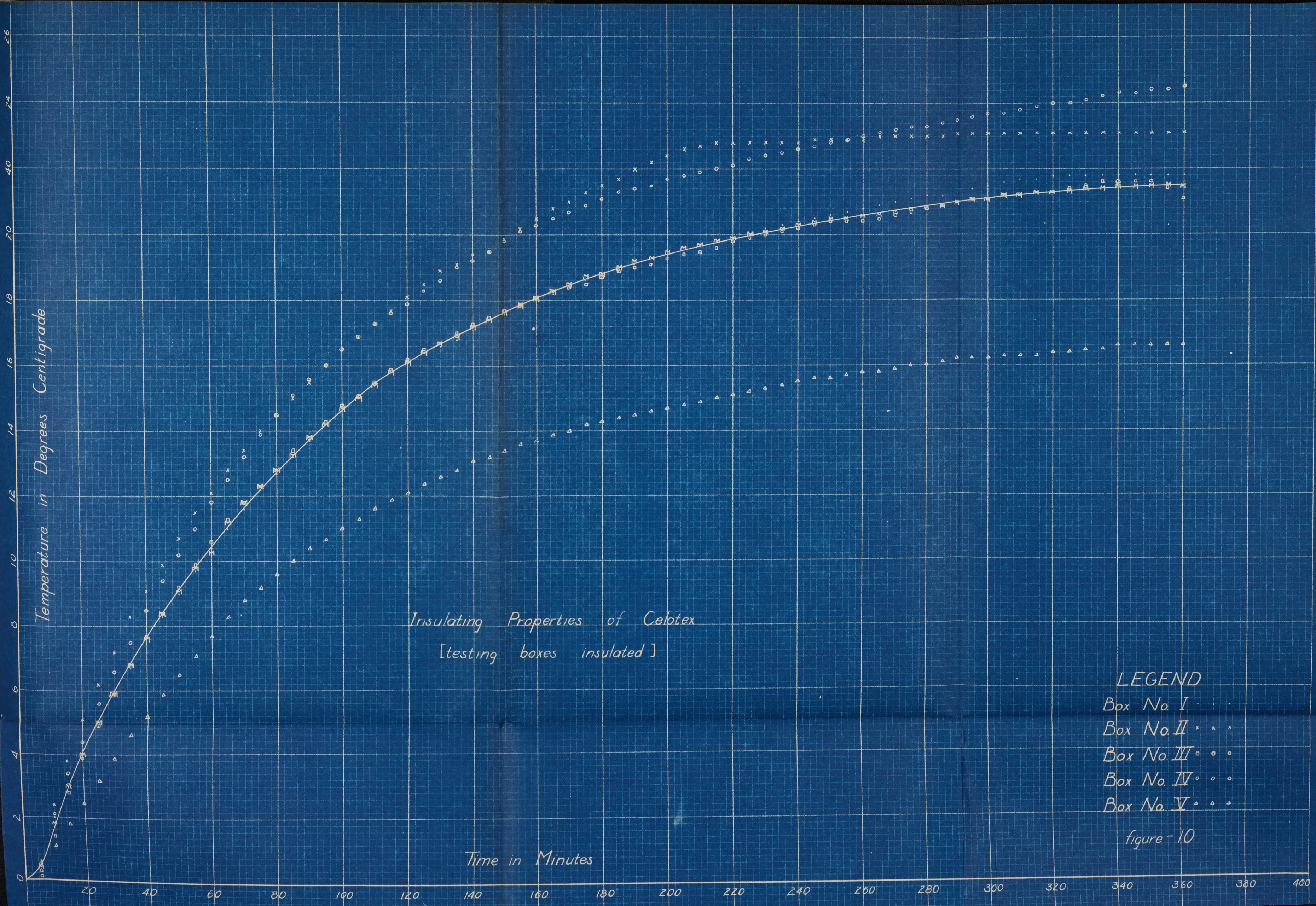
Insulating Properties of Celotex
[testing boxes insulated]

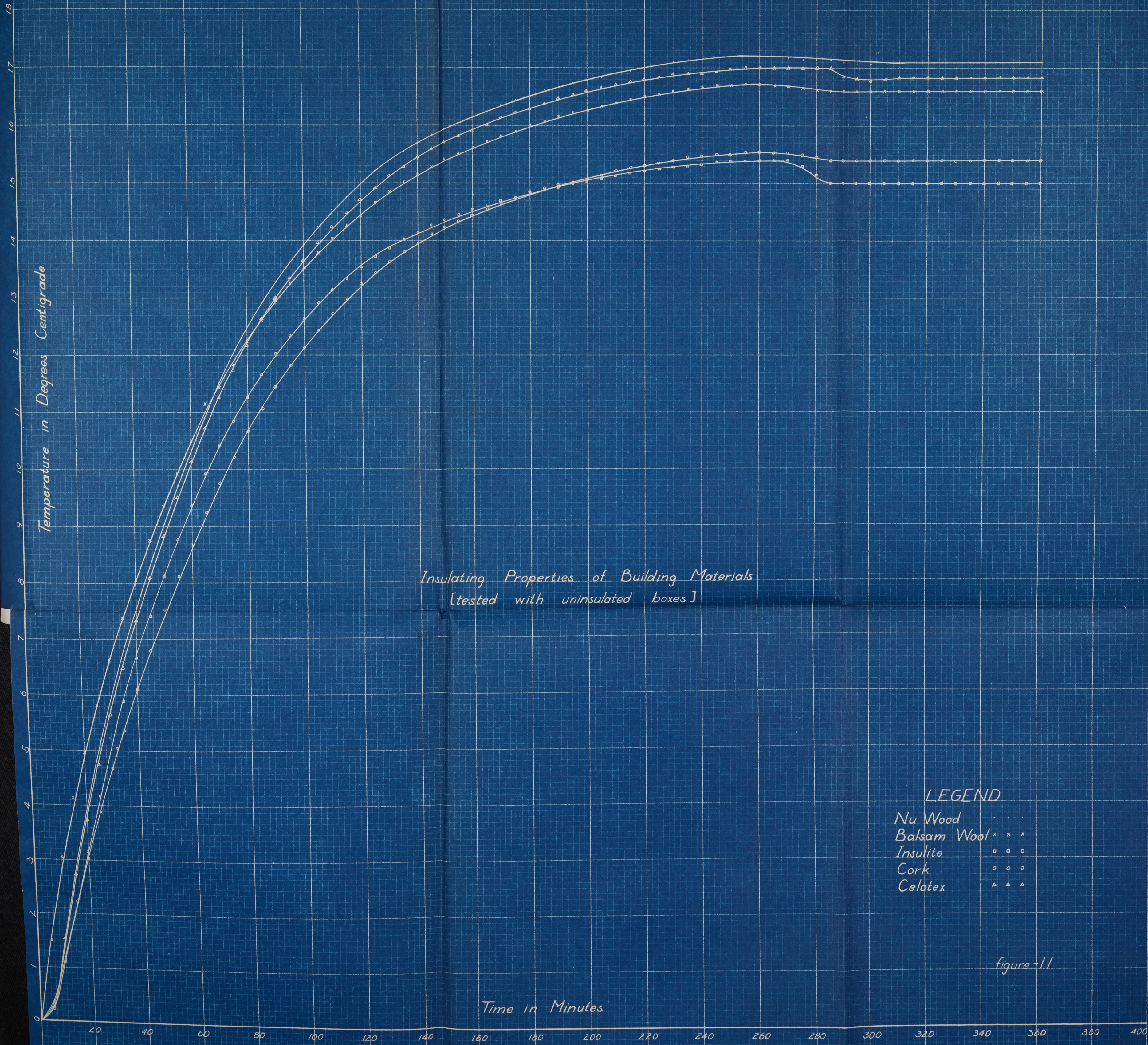
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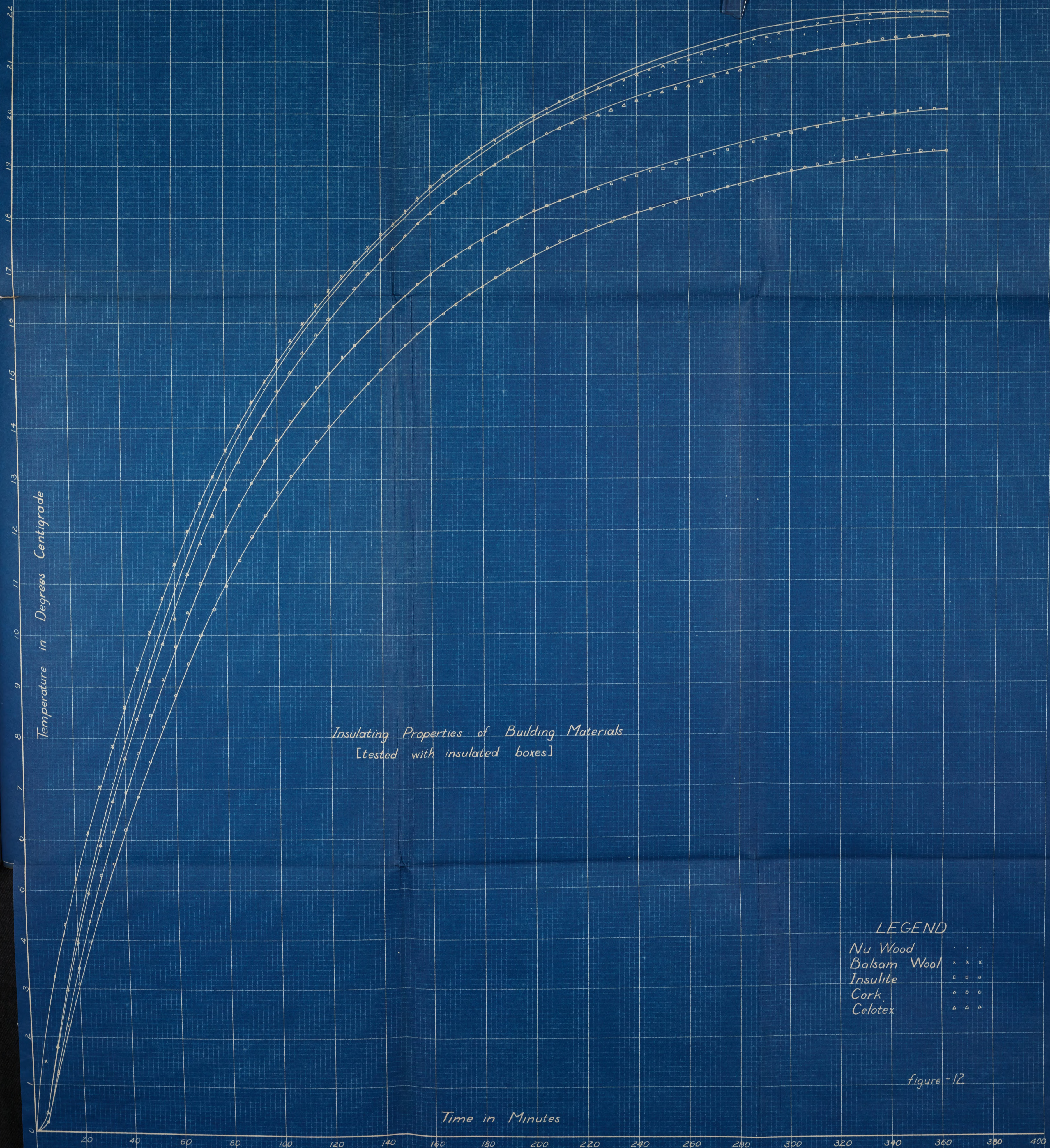
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figure - 10







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