DEPARTMENT OF CHEMICAL ENGINEERING

THESIS

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AN AUTOMATIC TEMPERATURE REGULATOR FOR DRYING OVENS.

There are many instances in quantitative chemical analysis where it is necessary to dry or "bake" the substance being examined at a certain temperature for an hour or longer. There are on the market many types of electrically heated drying ovens fitted with suitable regulators so that the analyst may adjust them to the desired temperature, turn on the current, and leave the rest to the regulator. These devices are very satisfactory, but unfortunately they are expensive so the average analyst must resort to the hand regulated, gas heated oven. The usual form of drying oven is simply a rectangular metal box supported on four legs, and is heated by a bunsen burner placed under it. A thermometer is inserted through the top of the oven and the operator must sit with one hand on the gas valve and his eye on the thermometer in order to get results that are anywhere near satisfactory. If he leaves the oven to itself for even a short length of time he is more than likely to find on his return that the temperature has climbed to a high point, which is often disastrous, particularly when working with the more volatile salts. Drying or "baking" has therefore become known as a tedious process.

The purpose of the writer in designing the device described here was to do away with these inherent disadvantages of the hand regulated oven. The aim was to produce a device that would be inexpensive, simple reliable, of a reasonable degree of accuracy, and rugged enough to withstand the action of the corrosive fumes that are always present in a chemical labratory. The first essential, of course, was a thermostatic element. The most familiar device of this type is the metallic thermostat consisting of two strips of metal of unequal coefficient of expansion rigidly fastened together. Such a strip will bend when its temperature is changed and this motion could be utilized to operate a gas valve, turning the burner under the oven down when the temperature rose, and up when it fell. This device seems at first thought to be the very thing for such a use; but a careful consideration of it brings forth many disadvantages. First, a more or less complicated linkage must be used in order to utilize the slight motion of the thermostat for controlling a valve. Second, the entire mechanism must be placed inside the oven, where it would be subjected to the destructive action of heat as well as the corrosive effect of acid or other fumes. Third, it would be neccessary to cut a hole in the side of the oven to install such a device.

While casting about for a thermostat that would get around some of these difficulties, the Sylphon, a device manufactured by the Fulton Company of Knoxville, Tennessee, came to the writer's attention. The Sylphon is made in many forms, but the one that seemed most suited for the work in mind was the type used on the Fulton Company's Tank Regulator. The thermostatic element is illustrated in section in figure 1. The Sylphon proper is indicated by A, and may best be described as a metal bellows that can be expanded and contracted in a manner similar to an accordion bellows. This "bellows" is made from a single piece of metal, there being no soldered joints to leak or give trouble. The Sylphon is connected to a bulb B by a copper tube. This bulb is partially filled with a volatile liquid, usually alcohol or either. On the application of heat to this bulb the liquid is volatilized and the device is filled with vapor or gas. The further application of heat, in accordance with the laws of

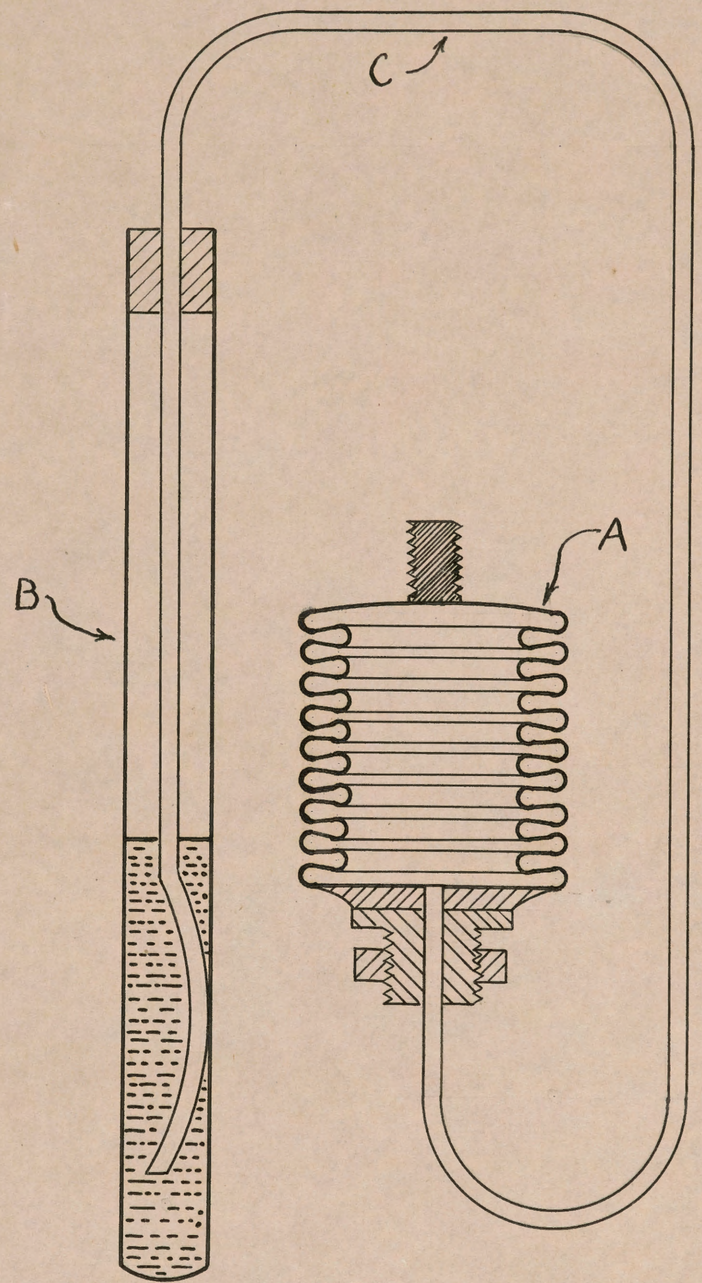


Fig. 1

thermodynamics, increases the pressure of the gas, which results in the expansion of the Sylphon. Similarly, a decrease in temperature lowers the pressure and causes the Sylphon to contract. According to data published by the manufacturer, the pressure of the gas increases 0.5 pounds per square inch for each rise of one degree Fahrenheit. It can be seen that this device does away with most of the difficulties mentioned above. The only part of the regulator in the oven is the bulb. The regulator proper is placed away from the heat and fumes of the oven. The motion of the Sylphon for a rise in temperature of 10 degrees Centigrade was found by experiment to be about 1/32 of an inch, and the pressure exerted by the Sylphon for such a rise is 9 pounds per square inch. The effective area in a $1\frac{1}{2}$ inch Sylphon is 0.875 square inches, so the pressure exerted would be 7.75 pounds, which is more than ample for operating a gas valve.

The Sylphon, however, has some disadvantages. It can be easily seen from the figures given above that for a temperature rise of say, 50 degrees Centigrade, considerable pressure is developed inside the Sylphon. If the walls of the device are made sufficiently heavy to withstand this pressure, they will be so thick as to hamper the movement of the "bellows". Consequently a temperature range of more than 50 degrees is impractical. Also, it requires an appreciable length of time for the bulb to absorb heat and transmit it as pressure to the Sylphon, so the regulation cannot be made extremely sensitive. The Sylphon is more sensitive to rises in temperature than to decreases, so the temperature is more apt to be too low than too high. This error can be minimized by fitting a spring to the Sylphon.

With these points in mind, the regulator of the form shown in plate 1 was constructed. The Sylphon was supported in an iron frame. Adjustment was effected by varying the tension of the spring H by means of the adjusting screw A. The motion of the device was transmitted to the valve V by means of the L-shaped arm W, which was pinned to the Sylphon at the point P and to the handle of the valve at X. Both of these pins worked in slots as shown in the drawing so that there was no binding when the parts moved. Tubes for the gas supply were connected at points GG. The bulb which is not shown in the drawing was thrust through a cork which was placed in one of the holes in the top of the oven. This regulator was fairly satisfactory and kept the temperature of the experimental oven constant within fairly close limits. There was some little motion lost in the linkage shown, however, and the device was rather erratic, now regulating well, now permitting wide variations. Results obtained with this form of regulator are tabulated in Data Sheet 1 and the accompanying curves.

The regulator shown in Plate II was then designed and constructed with a view of doing away with the difficulties of the first type. As before, the Sylphon was supported in an iron frame, and was provided with an adjustable spring. This time, however the Sylphon was directly connected to the globe valve V by the rod R, which passed through the hollow screw A. The gas tubes were connected to the pipes GG. The method of attaching the regulator is shown in Plate III. The gas by-pass shown was for the purpose of allowing sufficient gas to reach the burner to keep it burning even when the valve was completely closed. The operation of the regu-

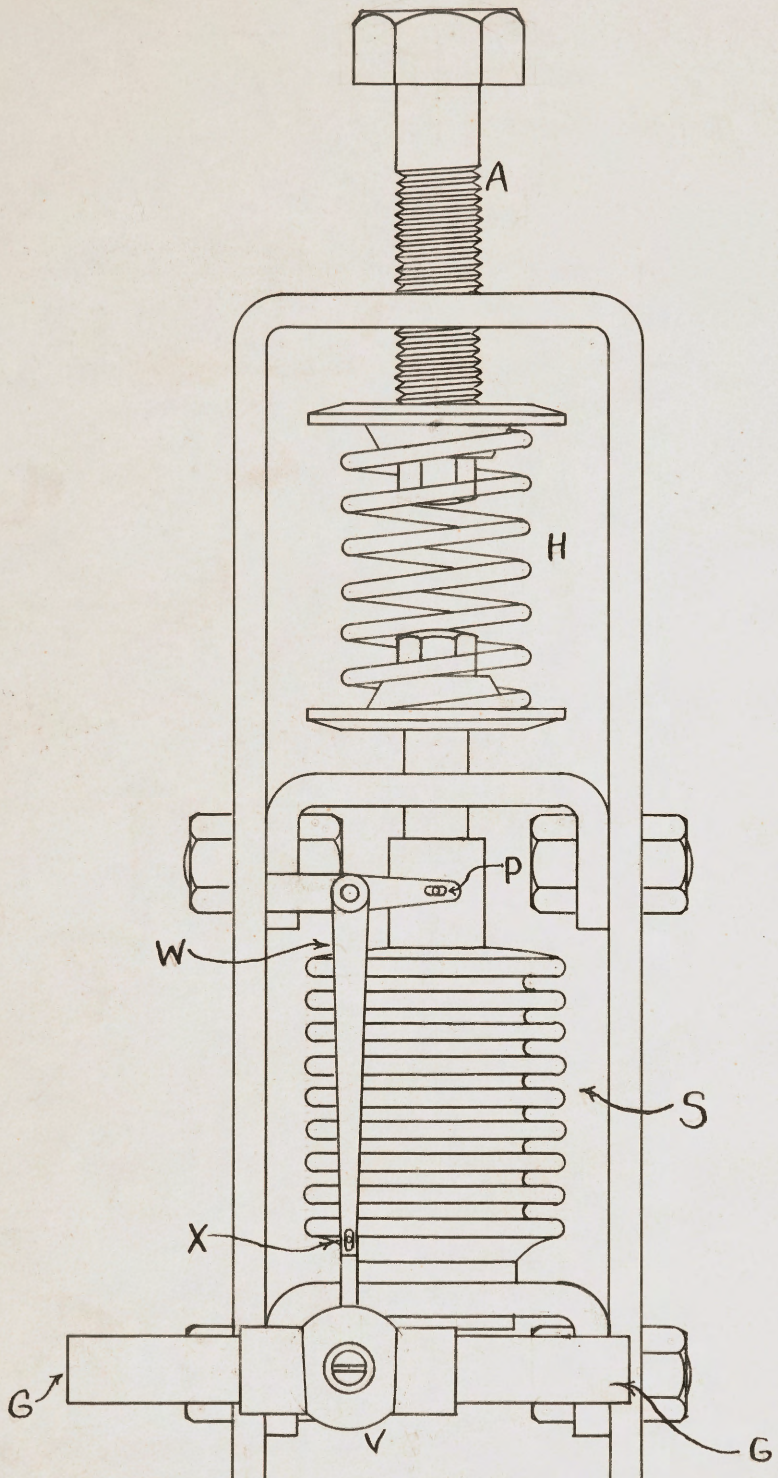


PLATE I

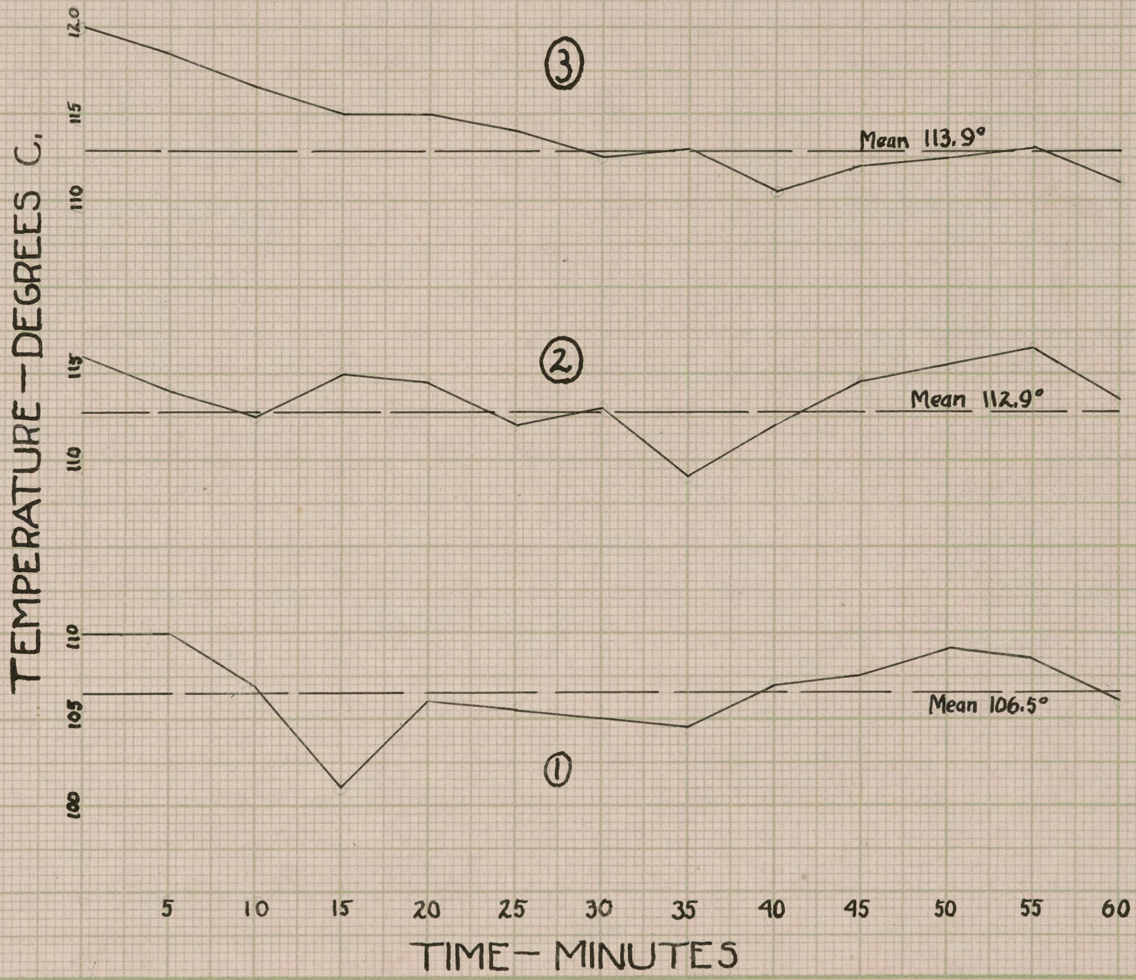
Full size

DATA SHEET I.

Temp. C

Reading	1	2	3
1	110.0	116.0	120.0
2.	110.0	114.0	118.5
3	107.0	112.5	116.5
4	101.0	115.0	115.0
5	106.0	114.5	115.0
6	105.5	112.0	114.0
7	105.0	113.0	112.5
8	104.5	109.0	113.0
9	104.0	112.0	110.5
10	107.0	114.5	112.0
11	107.5	115.5	112.5
12	109.0	116.5	117.5
13	108.5	113.5	111.0
Mean	106.5	112.9	113.9

Readings were taken at 5 minute intervals.



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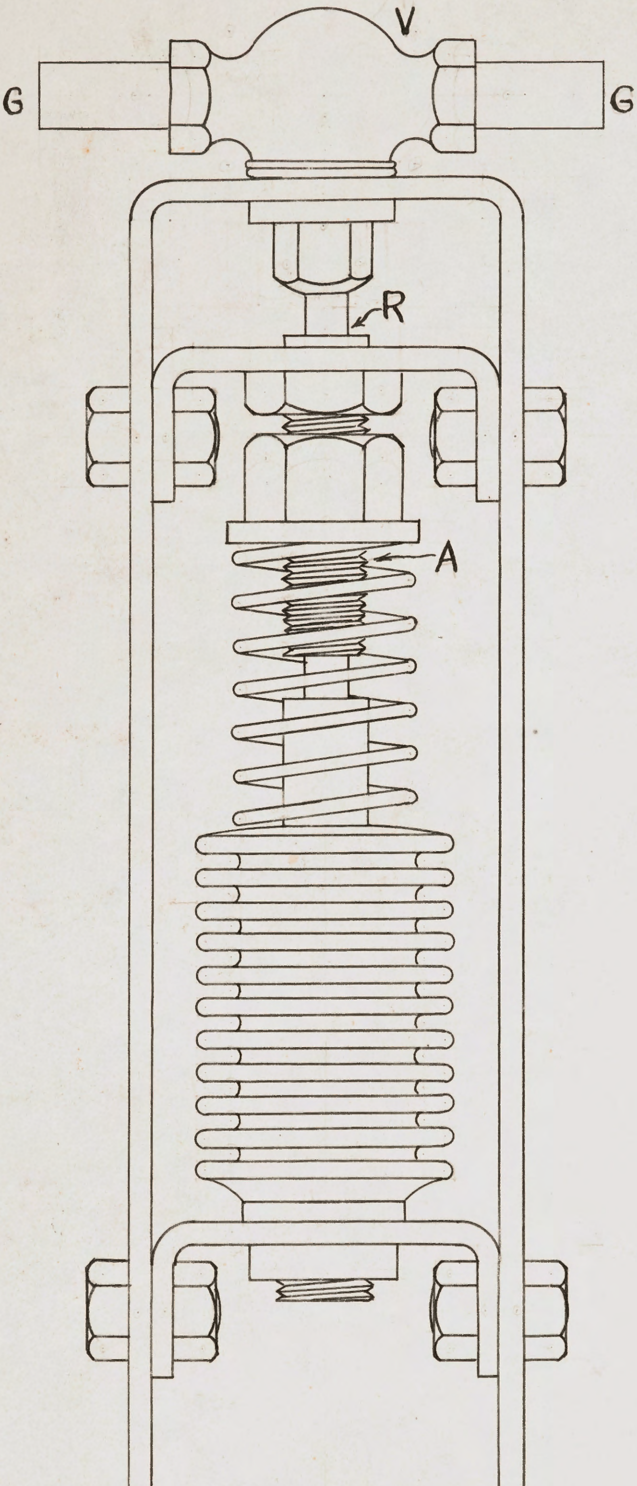


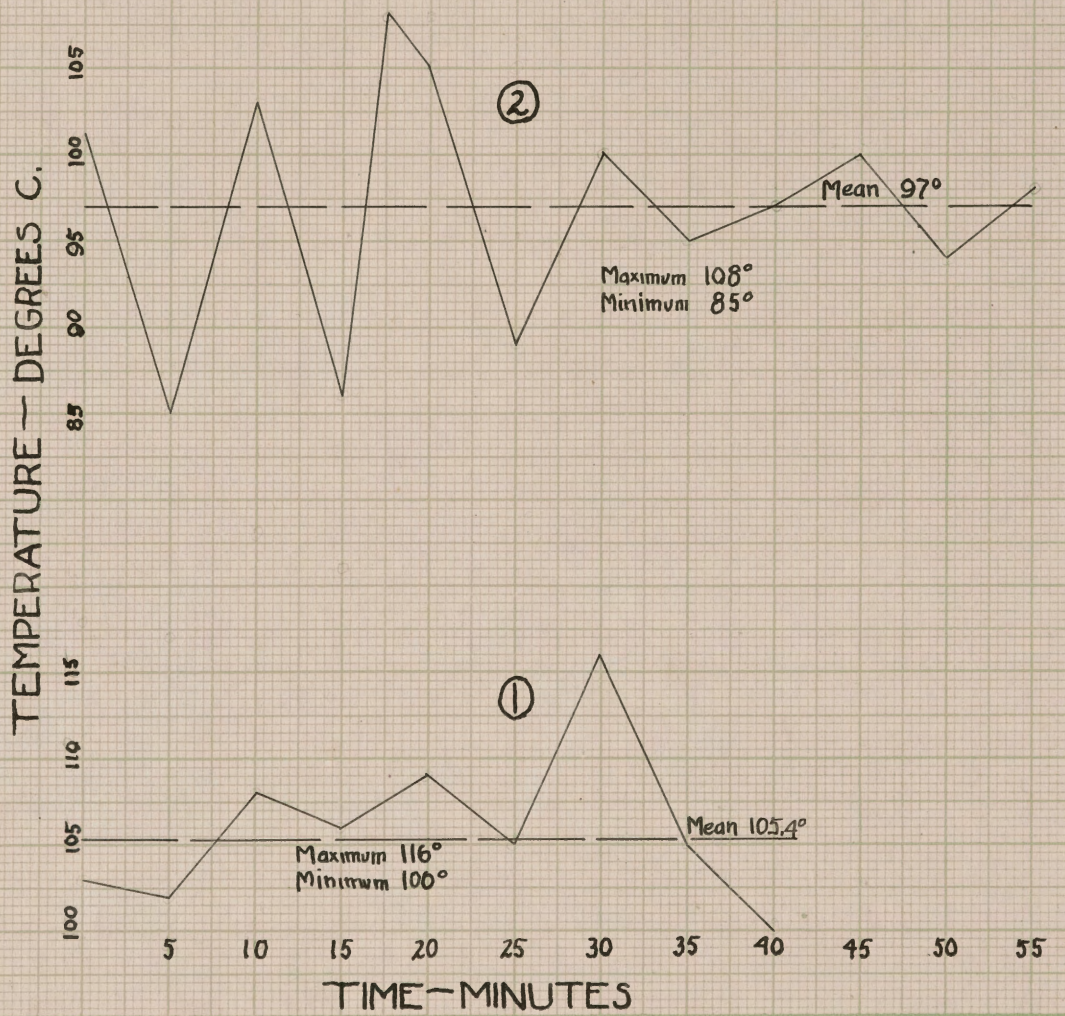
PLATE II

Full size

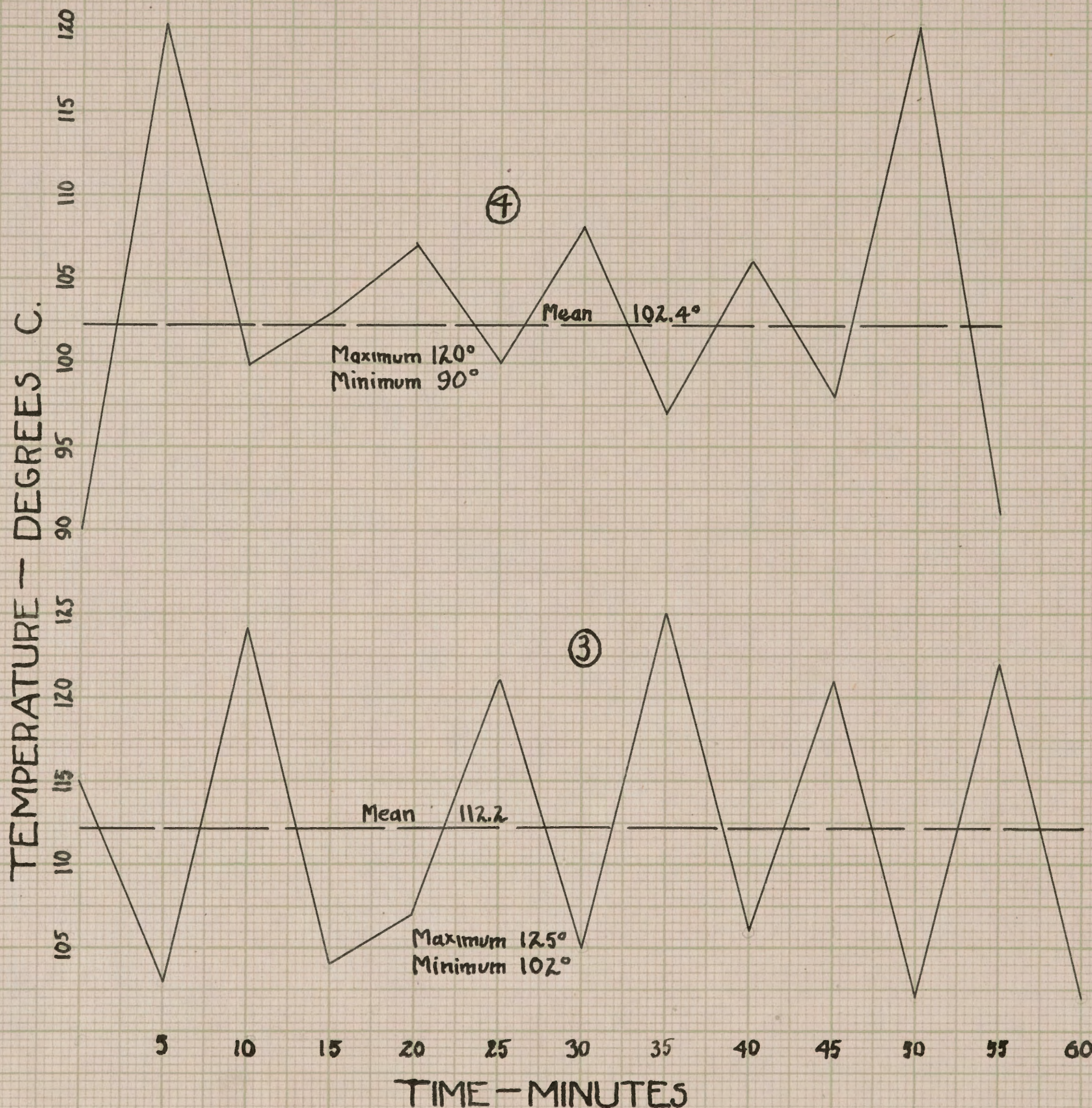
DATA SHEET II.

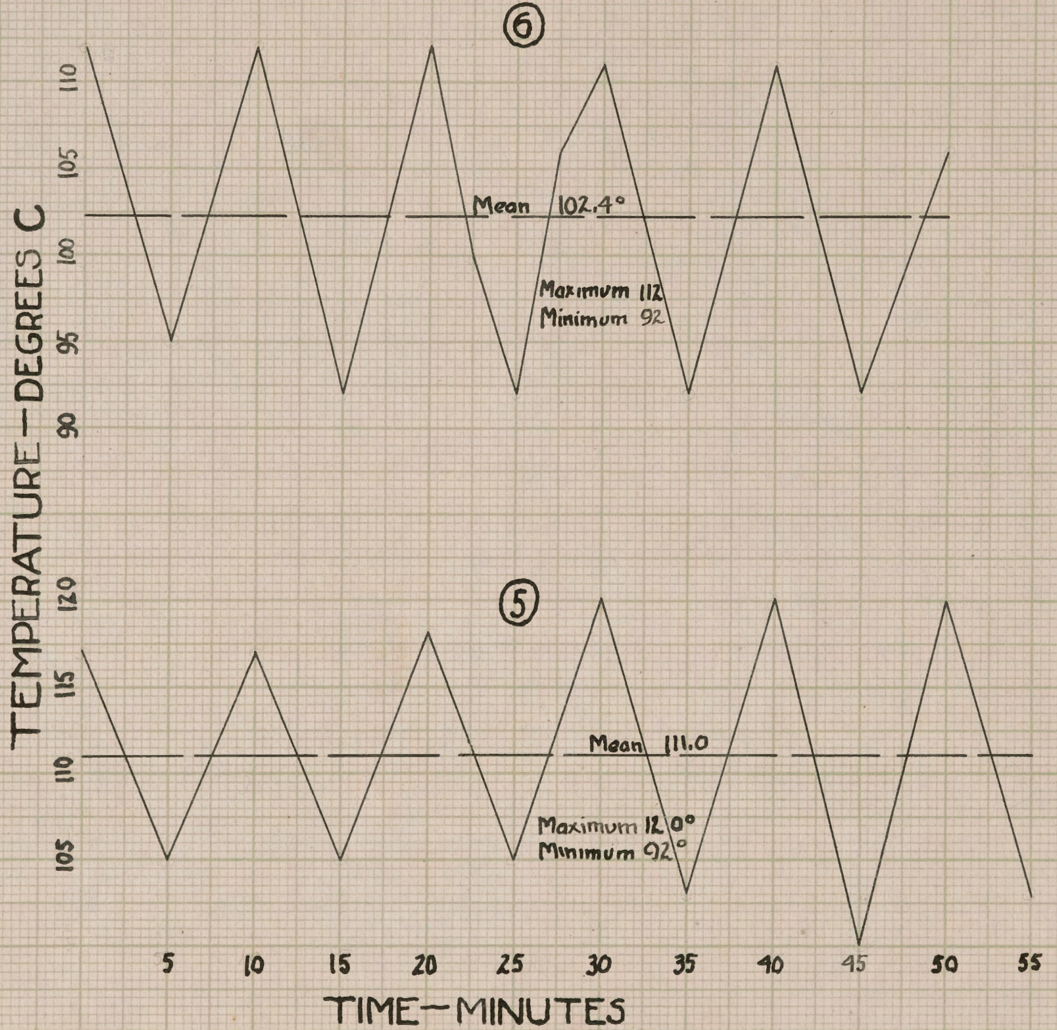
Reading	1	2	3	4	5	6
1	103	101	115	90	117	112
2	102	85	103	120	105	95
3	108	103	124	100	117	112
4	106	86	104	103	105	92
5	105	108	107	107	118	112
6	109	105	121	100	105	100
7	105	89	105	108	120	92
8	116	100	125	97	103	106
9	105	95	106	106	120	111
10	100	97	121	98	100	92
11		100	102	120	120	111
12		94	122	91	103	92
13		98	102			106
14						92
Mean	105.4	97	112.2	102.4	111.0	102.4

Readings were taken at 5 minute intervals.



TEMPERATURE — DEGREES C.
TIME — MINUTES
5 10 15 20 25 30 35 40 45 50 55
②
105
100
95
90
85
Mean 97°
Maximum 108°
Minimum 85°
①
115
110
105
100
Mean 105.4°
Maximum 116°
Minimum 100°


TEMPERATURE — DEGREES C.
90
95
100
105
110
115
120
④
Mean 102.4°
Maximum 120°
Minimum 90°
105
110
115
120
125
③
Mean 112.2
Maximum 125°
Minimum 102°
5
10
15
20
25
30
35
40
45
50
55
60
TIME—MINUTES



⑥
Mean 102.4°
Maximum 112
Minimum 92
⑤
Mean 111.0
Maximum 120°
Minimum 92°
TEMPERATURE – DEGREES C
110
105
100
95
90
120
115
110
105
5
10
15
20
25
30
35
40
45
50
55
TIME – MINUTES

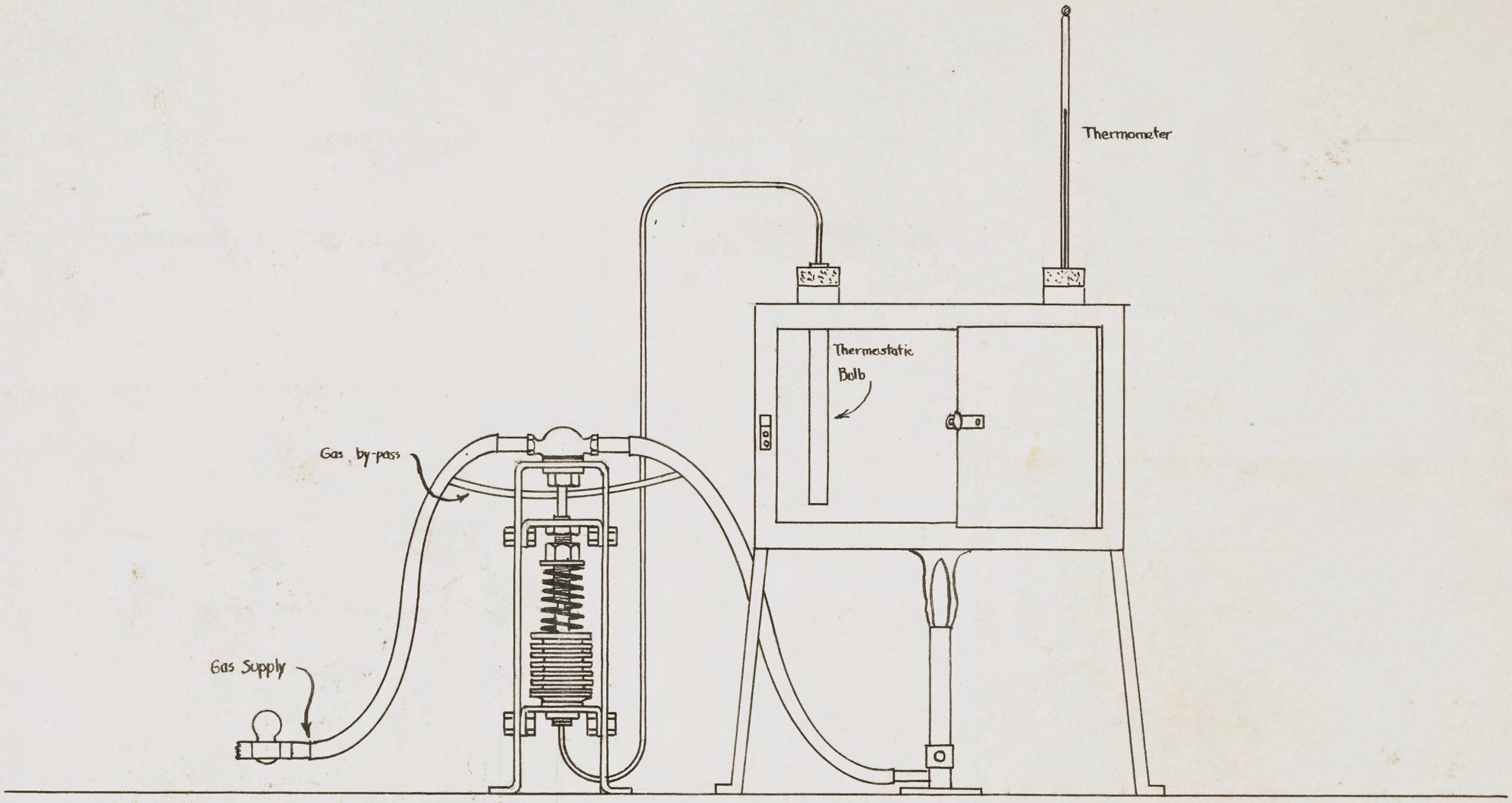


PLATE III

lator was extremely simple. All that was necessary to adjust it was to heat the oven to the highest permissable temperature, then relax the pressure on the spring until the valve closed. When the temperature of the oven had dropped about 20 degrees the burner would be turned on, heating the oven up to the predetermined temperature, when the thermostat would close the valve again.

This regulator, while not so sensitive as might have been desired, worked with great reliability and regularity, requiring absolutely no attention from the operator. A number of tests extending over varying periods of time were made by the writer. The results obtained on representative runs are given in Data Sheet II and the accompanying curves. The writer had hoped that the regulator would, after having run for a little while, adjust the flame to give an approximately constant temperature, but a study of the curves shows that it did not. Rather, it would "see-saw" from the maximum to the minimum temperature. The difference between maximum and minimum was reasonably small, however, so that this error was not serious. Altogether, the regulator performed in a very satisfactory manner, especially with regard to reliability, and demonstrated conclusively that such a device was practical.

Taking into consideration the results of the experiments described above, the writer feels no hesitancy in stating that a regulator similar to the above could be made that would be just as reliable and more accurate than the one constructed. I believe that a non-adjustable instrument, operating at but one temperature could be made that would hold the temperature constant within 2 degrees plus or minus. Such a device would be far more desirable than the clumsy ovens now constructed for constant temperature work. I am referring to the double walled ovens which use a liquid of known boiling point to secure the constant temperature. For successful operation the solution used must be made up very carefully, and a condenser must be attached to prevent the boiling away of the more volatile constituents of the solution. When set up this apparatus is very clumsy and troublesome. The regulator built on the principle I have described would be compact, reliable and efficient, and sufficiently accurate for chemical and bacteriological investigations.