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BUREAU OF ENGINEERING

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Second Partial Report
on
Investigation of Dehumidifying Agents
for Submarines - Characteristics
of Magnesium Chloride as a
Desiccant.

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Table of Contents

| | Page |
|--|------------|
| Introduction | |
| (a) Authorization | 1 |
| (b) Statement of Problem | 1 |
| (c) Known Facts Bearing on the Problem | 1 |
| (d) Theoretical Considerations | 1 |
| (e) Original Work Done at this Laboratory | 2 |
| Methods | |
| (a) Preparation of Materials | 2 |
| Data Obtained | 4 |
| Conclusions and Recommendations | 6 |
| Summary | 8 |
| Appendix | (a) to (d) |

ABSTRACT

This report discusses experiments on the characteristics of magnesium chloride as a dehumidifying agent for submarines and compares its characteristics with those of other drying agents. From consideration of the five factors -

- (a) The weight efficiency
- (b) Cost
- (c) Commercial availability
- (d) Rate of removal of water
- (e) Possible corrosive and other deleterious effects,

as applied to calcium chloride, lithium chloride, magnesium chloride, and some mixtures of these, recommendations are made as to the particular drying agent to use in specific applications. For example, where high weight efficiency is required, lithium chloride is recommended; for low cost, calcium chloride is best.

| | |
|----------------------------------|-----|
| MgCl ₂ | 71% |
| MgO | 10% |
| H ₂ O (by difference) | 19% |

M2 - MgCl₂.6H₂O was heated in a vacuum at 100°C. for nine hours. Analysis gave:

| | |
|----------------------------------|-----|
| MgCl ₂ | 59% |
| MgO | nil |
| H ₂ O (by difference) | 41% |

M4 - One part of MgCl₂.6H₂O was heated with 1-1/2 parts NH₄Cl in a stream of dry HCl until all of the NH₄Cl had sublimed. The temperature was then increased until the product melted. Analysis gave:

| | |
|----------------------------------|-------|
| MgCl ₂ | 98.5% |
| MgO | .35% |
| H ₂ O (by difference) | 1.1% |

A fourth sample of anhydrous magnesium chloride was obtained from the Dow Chemical Co. of Midland, Michigan, and analyzed as follows:

| | |
|----------------------------------|-------|
| MgCl ₂ | 95.5% |
| MgO | 1.2% |
| H ₂ O (by difference) | 3.3% |

It was in the form of flakes.

8. Samples of mixtures of magnesium chloride with calcium chloride and lithium chloride were also made.

MC1 - Twenty grams of anhydrous CaCl₂ were mixed with eighty-seven grams of MgCl₂.6H₂O and sufficient water was added to dissolve the two. The mixture was then heated to 152°C., and on cooling solidified to a hard mass. It was not analyzed but probably contained about 40% water.

MC2 - One hundred grams of CaCl₂ (anhydrous) were mixed with 75 grams of MgCl₂.6H₂O and sufficient water was added to dissolve the two. This is the proportion of the salts present in tachydrate. The solution was then heated to 150°. Loss of weight indicated that the residue contained 30% water.

MC2A - The preceding sample was further dehydrated under vacuum at 100°C. It was not analyzed.

MC3 - Fifty grams CaCl₂ were mixed with 105 grams MgCl₂.6H₂O and sufficient water was added to dissolve the mixture.

anhydrous lithium chloride and the lithium chloride being in turn compared with calcium chloride. In every other case the comparison with calcium chloride is direct.

11. Plates 1, 2, 3, 5 and 6 show curves comparing various samples of magnesium chloride with granular calcium chloride. Aside from samples M1 and M2 which were quite impure, the magnesium chloride was always better than calcium chloride both in rate of absorption of water and in weight efficiency. With the impure sample M1, the initial rate was quite high compared with that of calcium chloride, but the weight efficiency was definitely lower. The sample M2 was inferior to calcium chloride in all respects, and will not be considered further. At room temperature the initial rate of absorption of water by magnesium chloride was about 20 to 40% greater than the corresponding rate for calcium chloride, and the weight efficiency at equilibrium was approximately 25% higher. These figures are approximately correct for all of the relative humidities investigated.

12. At low temperatures (30° to 40°F.) magnesium chloride is definitely superior to calcium chloride in so far as the rate of absorption is concerned. This is plainly shown in Plates 1 and 5, where the rate of absorption by magnesium chloride is nearly twice that of calcium chloride. It should also be noted that this high rate of absorption is maintained over a long range of the absorbing period, especially in the case of the purer magnesium chloride (Plate 5).

13. In general, the mixtures of magnesium chloride and calcium chloride are inferior to calcium chloride, the only possible exception being MC4. This latter mixture is a fairly pure mixture of the chlorides. An examination of the curve for this desiccant (Plate 6) shows the rate of absorption is definitely inferior to that of calcium chloride, but that the weight efficiency is slightly higher (10%). However, this slightly greater weight efficiency is more than offset by the very slow initial rate, and the considerably higher cost of the mixture. None of the other mixtures of magnesium chloride and calcium chloride are worth considering.

14. Plates 6, 7 and 8 show the results obtained with mixtures of lithium chloride and magnesium chloride. The curves on Plate 6 show that the pure magnesium chloride has a higher initial rate than the lithium chloride or the mixture LML. This is due to the physical states of the substances, the magnesium chloride being granular, while the others were in the form of small lumps. However, in the middle stages of absorption the mixture LML was definitely a faster absorbent

than either magnesium chloride or lithium chloride. The final weight efficiency of the mixture, however, was somewhat lower than that of lithium chloride. The slow initial rates of all of these substances as compared with calcium chloride is again due to their physical states. The calcium chloride used as a comparison agent was in the form of small granules, exposing a large surface to the moisture in the air. Plate 7 again compares LM1 and lithium chloride with granular calcium chloride, and the results are very similar.

15. Plate 8 compares the other mixtures of lithium chloride and magnesium chloride with pure lithium chloride, but none of them are as fast or as efficient as the mixture of LM1. As may be seen from the curves, their rates of absorption are only 60% to 80% that of pure lithium chloride, and their weight efficiencies are 50% to 85% that of lithium chloride. The weight of absorption of the best of these other mixtures (LM2) is 25% to 40% lower than the rate of LM1 or about the same as that of pure magnesium chloride. In view of this, and taking into consideration the high prices of these mixtures (LM2, LM3 and LM4) they are not worth considering as drying agents.

CONCLUSIONS AND RECOMMENDATIONS

16. In concluding this report and making recommendations, several factors must be borne in mind which will first be listed.

- (a) Weight efficiency of drying agent.
- (b) Cost per pound of removing water.
- (c) Rate of removal of water.
- (d) Corrosive action of desiccant or of its solution.

The particular problem at hand will determine which of these factors is the most important. Thus, where the maximum weight allowed is limited, the weight efficiency may be more important than the cost of removing water. In certain cases it may be necessary to remove the water rapidly and again cost may be a minor factor. Table 1 lists the weight efficiencies and costs per pound of removing water for the better drying agents at one typical temperature and initial relative humidity.

17. Calcium chloride normally sells for about two to three cents a pound, and if the desired relative humidity is not less than 30% this price compares favorably, or is considerably lower than that of quicklime under the most favorable conditions. In a later report certain disadvantages of quicklime will be shown, which raise its cost of water removal appreciably. In so far as cost is concerned, calcium chloride is superior to all of the other drying agents studied.

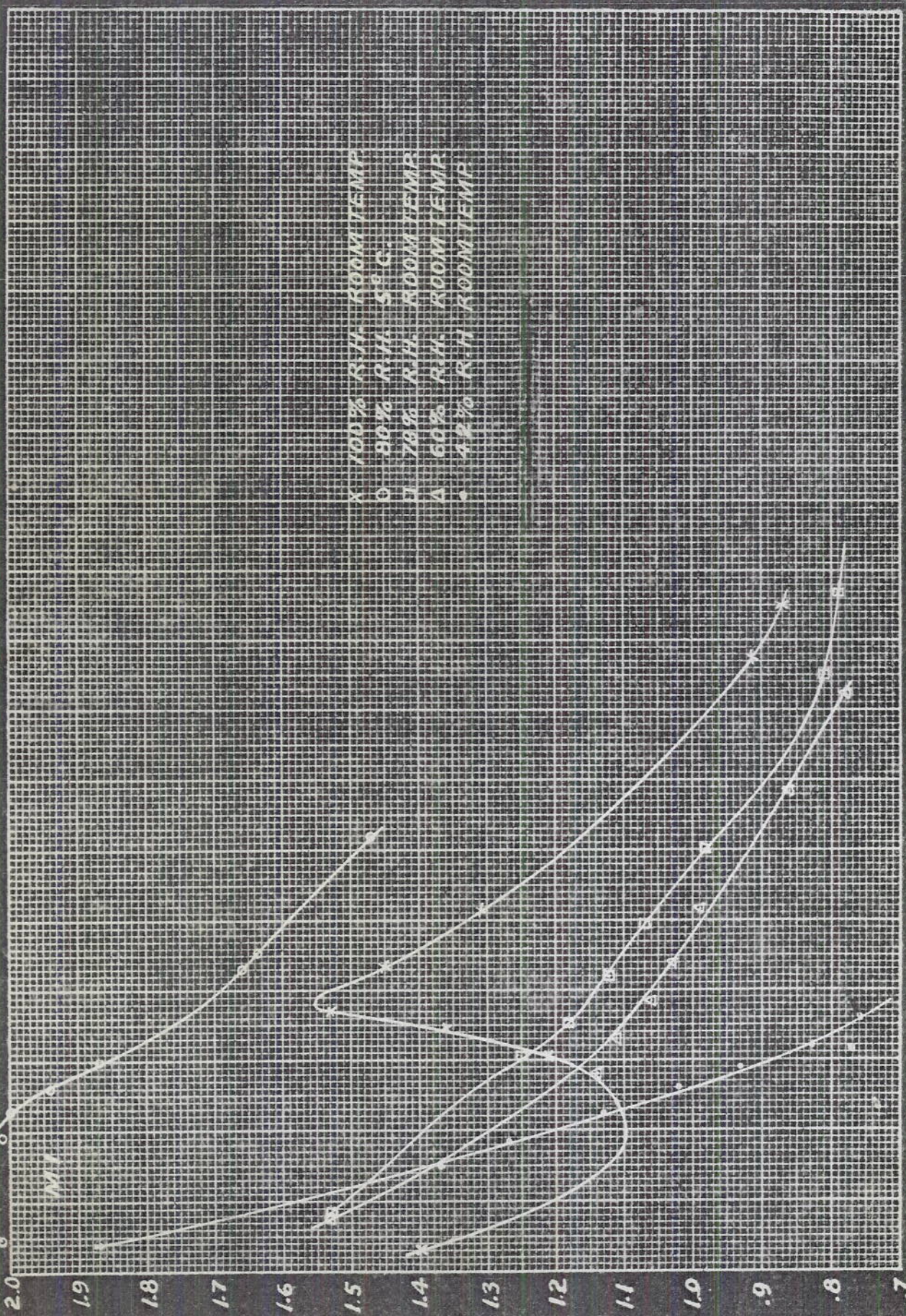
Table 1

Room temperature - 90°F.
 Volume of space - 1000 cu.ft.
 Initial relative humidity - 90%.
 Total weight of water vapor in 1000 cu.ft. - 13,311 grains.

| | 70 | 60 | 50 | 40 | 30 | 20 | 10 |
|-----------------------------------|----------|---------|---------|----------|---------|---------|---------|
| Final relative humidity | | | | | | | |
| Grains of water remaining | 10353 | 8874 | 7395 | 5916 | 4437 | 2958 | 1479 |
| Grains water removed | 2958 | 4437 | 5916 | 7395 | 8874 | 10353 | 11832 |
| Pounds water removed | 0.422 | 0.634 | 0.848 | 1.056 | 1.268 | 1.480 | 1.691 |
| Pounds anhydrous salt needed - | | | | | | | |
| Calcium chloride | 0.159 | 0.298 | 0.490 | 0.734 | 1.07 | 1.61 | 2.82* |
| Magnesium chloride | 0.136 | 0.240* | 0.36* | 0.50* | | | |
| Lithium chloride | 0.105 | 0.195 | 0.31 | 0.53* | 0.75* | 1.14* | ca.2.1* |
| LML | 0.117 | 0.213 | 0.33 | 0.5 | | | |
| Quicklime (pure) | 1.31 | 1.97 | 2.64 | 3.29 | 3.95 | 4.61 | 5.26 |
| Cost per pound of water removed - | | | | | | | |
| Calcium chloride at \$0.01/lb. | \$0.0016 | \$0.003 | \$0.005 | \$0.0073 | \$0.011 | \$0.016 | \$0.03 |
| Calcium chloride | 0.0032 | 0.006 | 0.01 | 0.015 | 0.022 | 0.032 | 0.06 |
| Calcium chloride | 0.005 | 0.009 | 0.015 | 0.022 | 0.033 | 0.048 | 0.09 |
| Calcium chloride | 0.008 | 0.015 | 0.025 | 0.037 | 0.055 | 0.080 | 0.15 |
| Magnesium chloride | 0.0095 | 0.017 | 0.025 | 0.035 | | | |
| Lithium chloride | 0.105 | 0.195 | 0.31 | 0.53 | 0.75 | 1.14 | 2.10 |
| Lithium chloride | 0.131 | 0.244 | 0.387 | 0.66 | 0.94 | 1.42 | 2.62 |
| LML | 0.09 | 0.17 | 0.26 | 0.39 | | | |
| Quicklime (90%) | 0.009 | 0.013 | 0.018 | 0.022 | 0.027 | 0.031 | 0.036 |

* Extrapolated value.

N. R. L. 81A



X 100% RH ROOM TEMP
O 90% RH 5% C
Δ 70% RH ROOM TEMP
A 60% RH ROOM TEMP
• 40% RH ROOM TEMP

H₂O/CaCl₂
MI/H₂O

PLATE 1

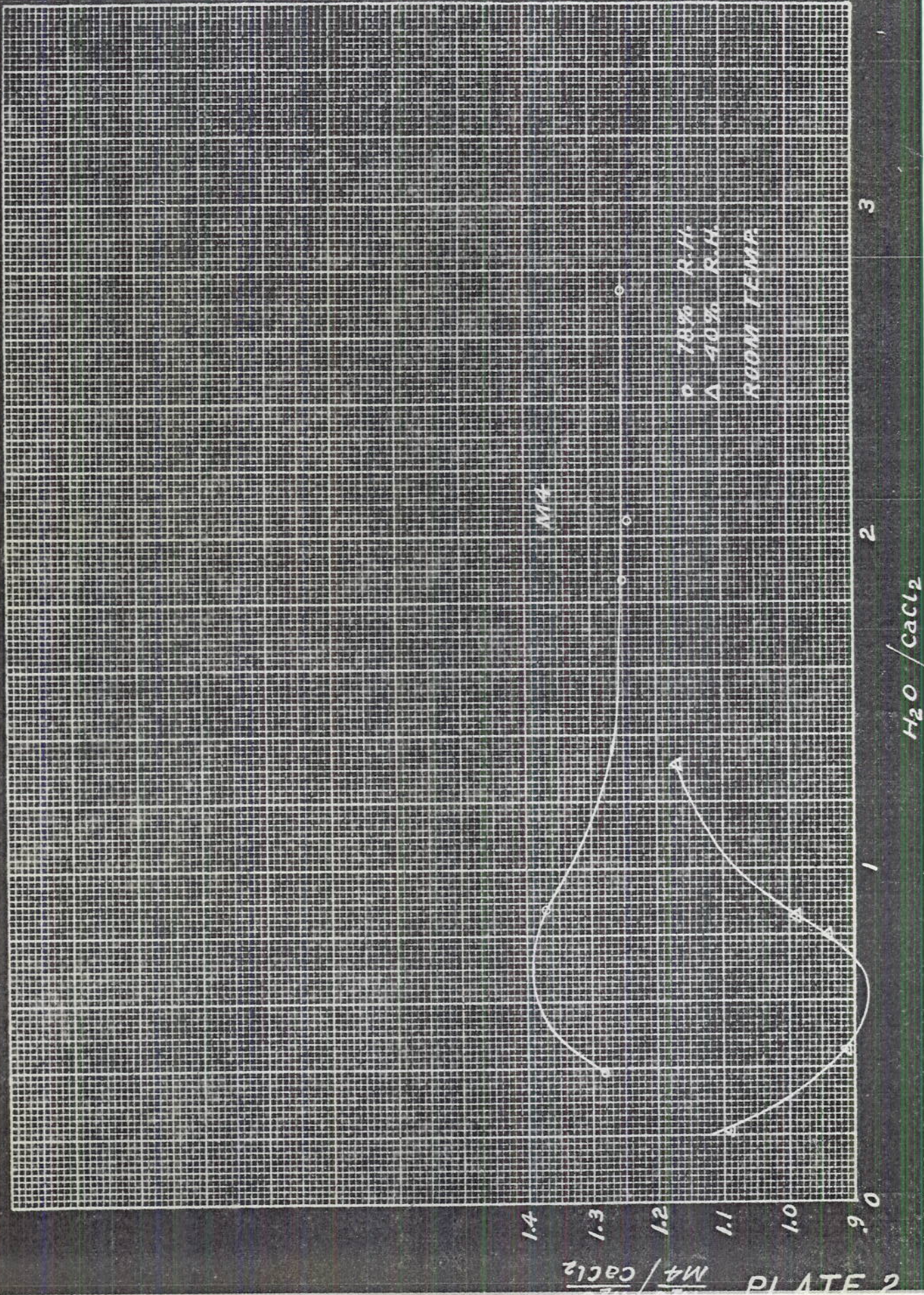
3

2

H₂O/CaCl₂

1

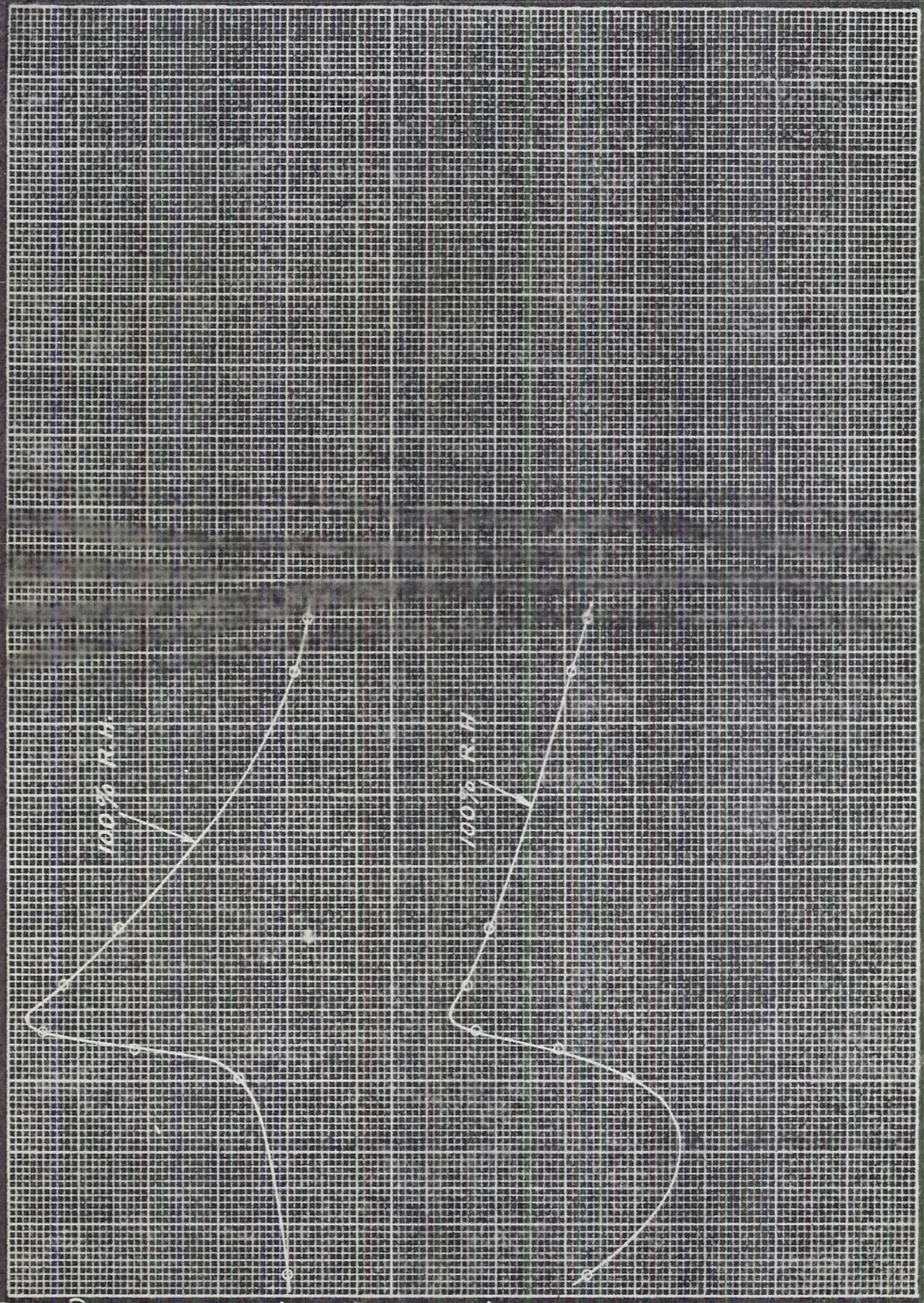
0



N. R. L. 34A

PLATE 2

H₂O / CaCl₂



3

2

1

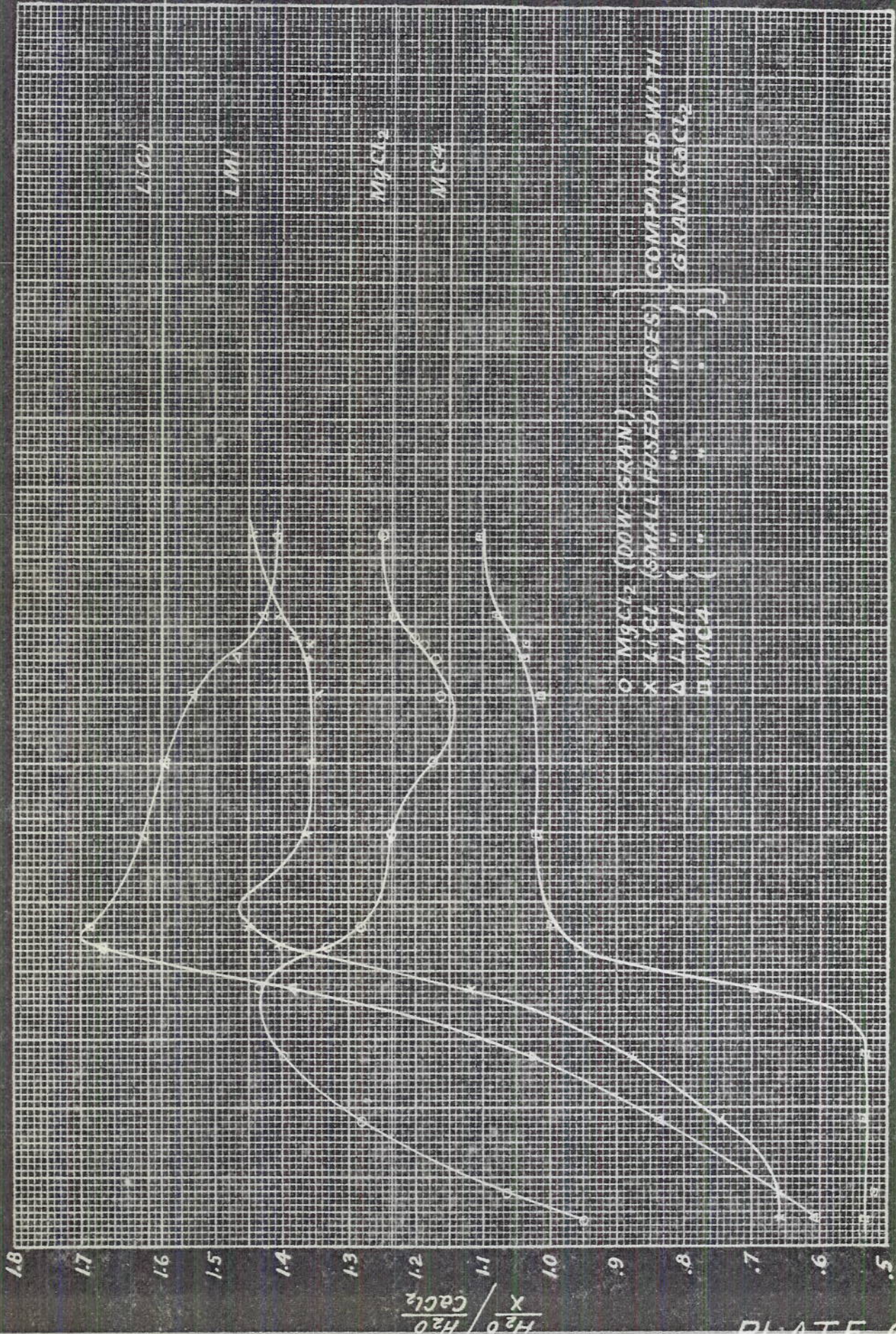
0

H₂O/CaCl₂

$\frac{H_2O}{M_2} / \frac{CaCl_2}{H_2O}$
 $\frac{M_2}{CaCl_2}$

PLATE 2

N. R. L. 34A



N. R. L. 814

3

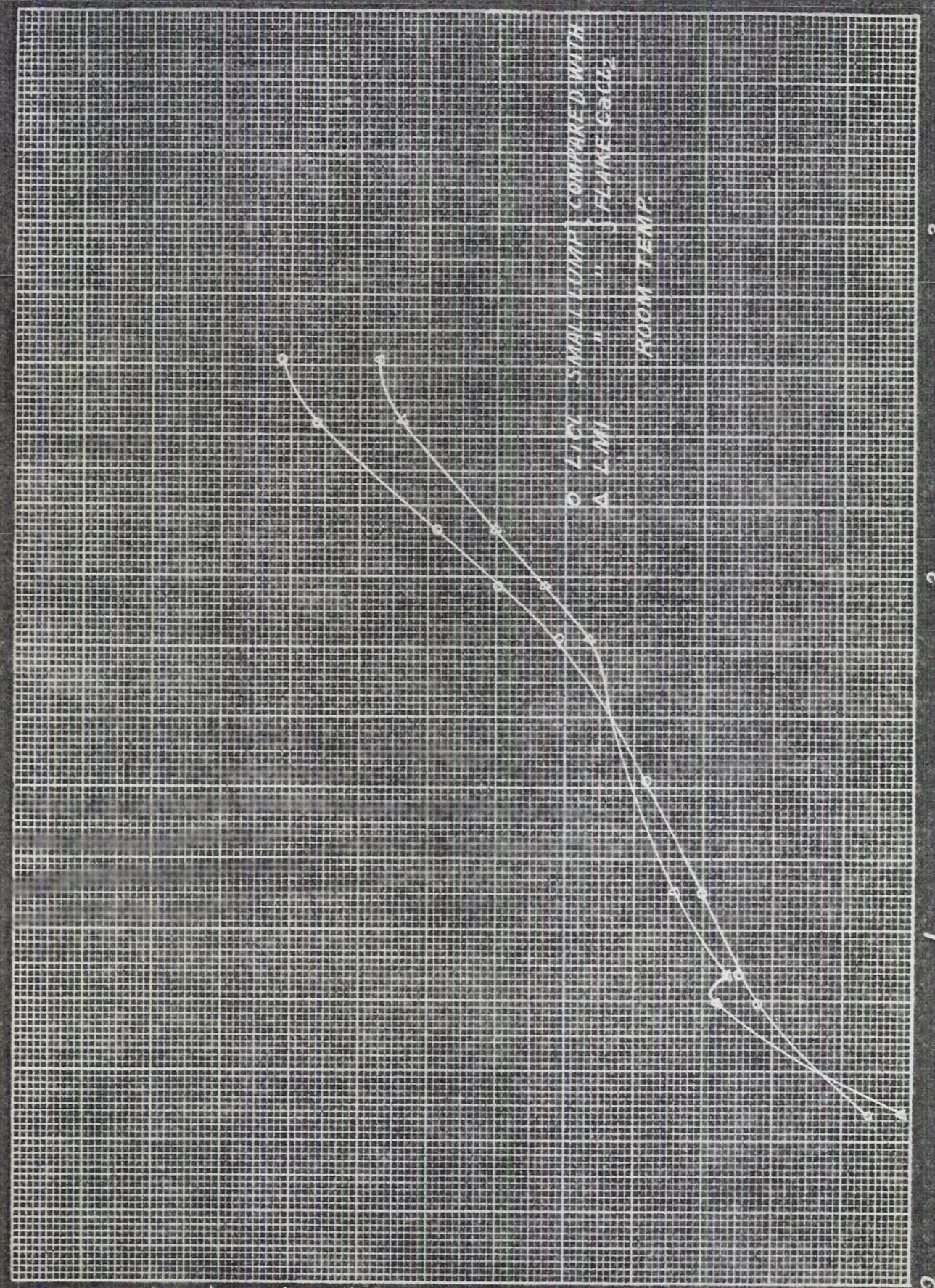
2

1

$H_2O/CaCl_2$

PLATE C

0.1% SMOKE (LOW) CONCENTRATION
6.1 M, 1.1 M, 0.5 M
XOCHM 1511



3

2

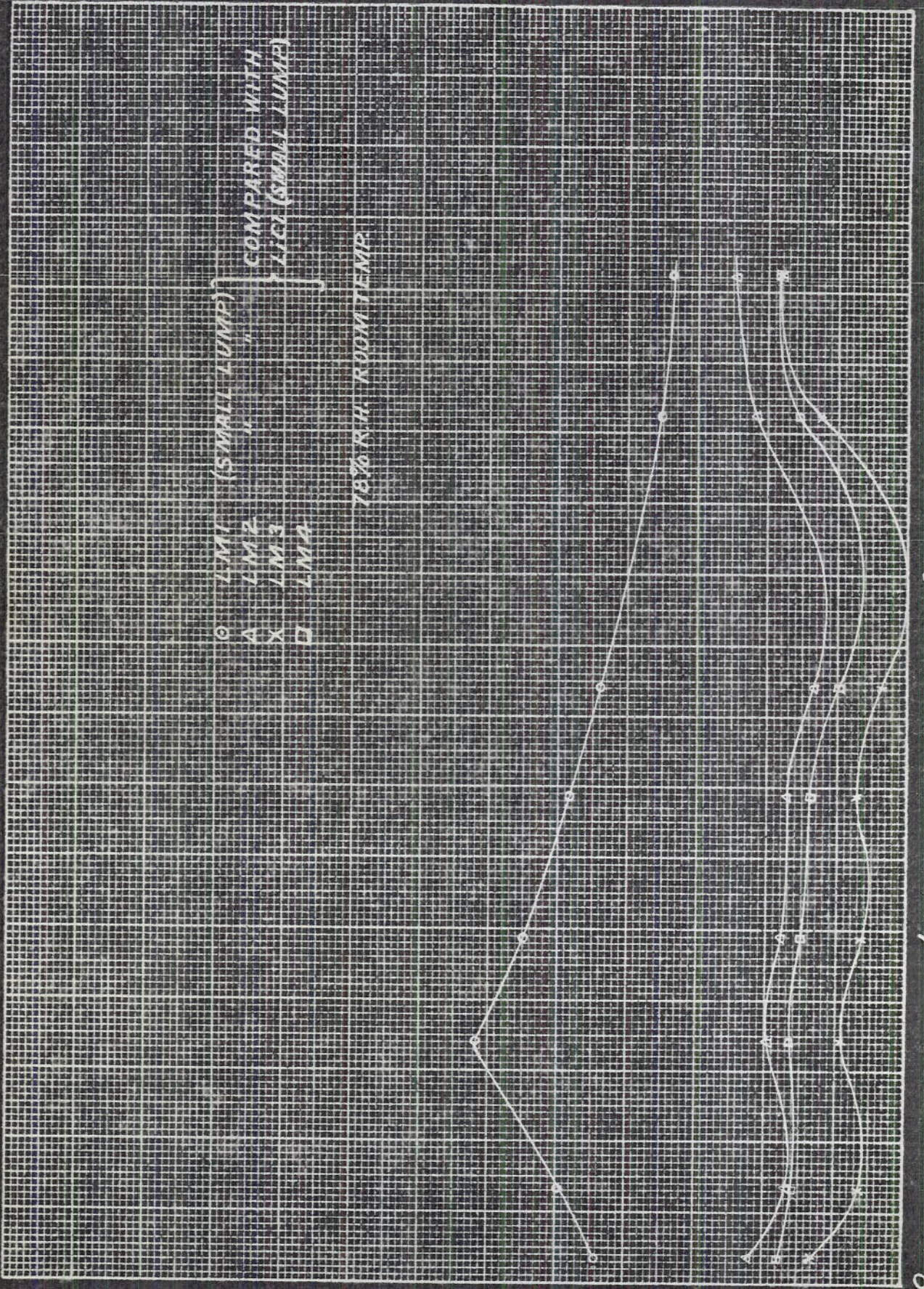
$H_2O / CaCl_2$

1

0

N. R. J. 81A

N. R. J., BIA



○ L.M. (SMALL LUMP)
△ L.M. 2
× L.M. 3
□ L.M. 4

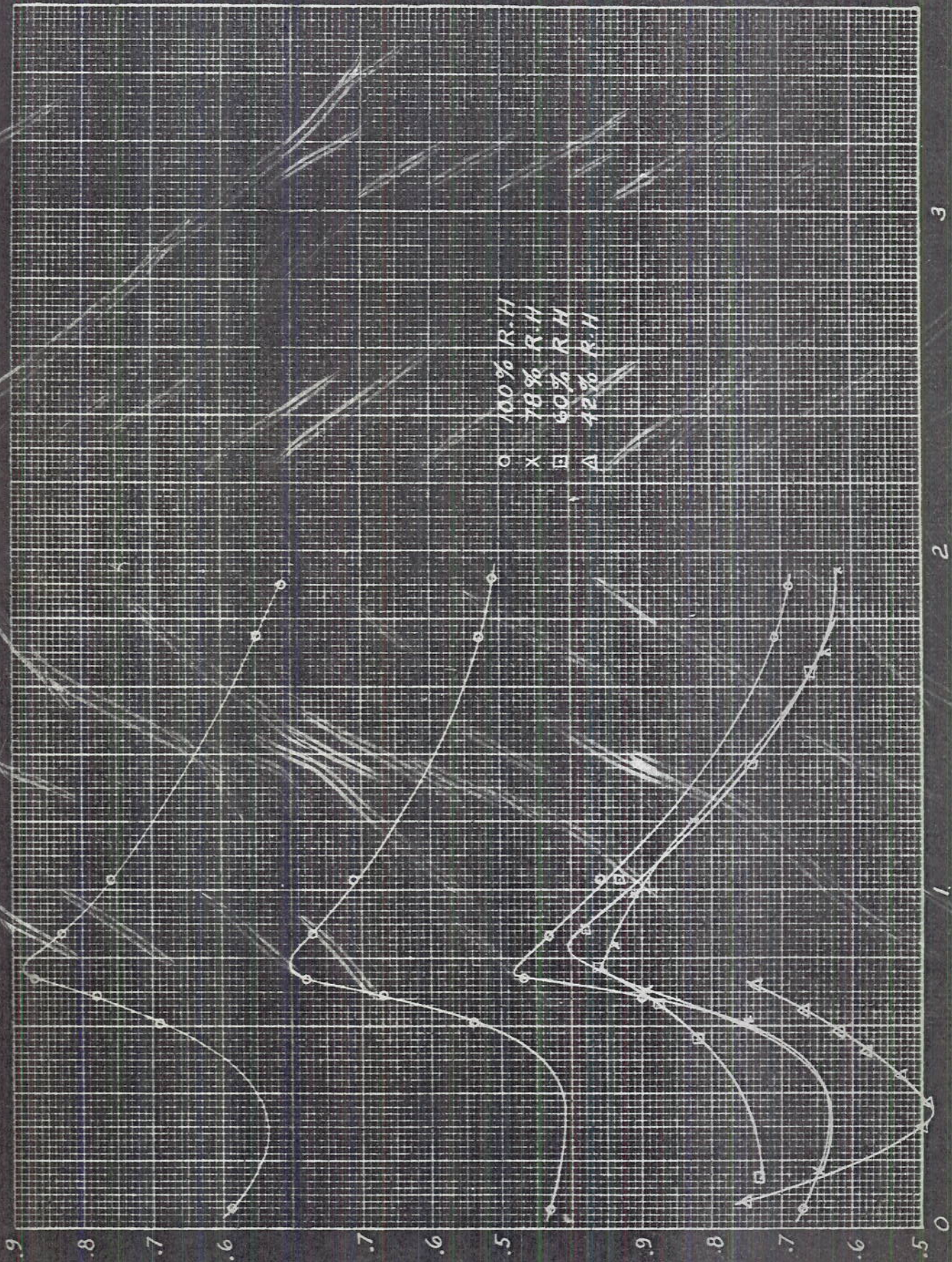
COMPARED WITH
LiCl (SMALL LUMP)

1.3% N.H. ROOM TEMP.

$\frac{H_2O}{LiCl} \times \frac{H_2O}{LiCl}$

PLATE 8

1
2
3
 $H_2O / LiCl$



○ 100% R.H.
× 78% R.H.
□ 60% R.H.
△ 42% R.H.

3

2

1

0

H₂O/CaCl₂

H₂O / CaCl₂
MCl₂ / CaCl₂

H₂O / CaCl₂
MCl / CaCl₂

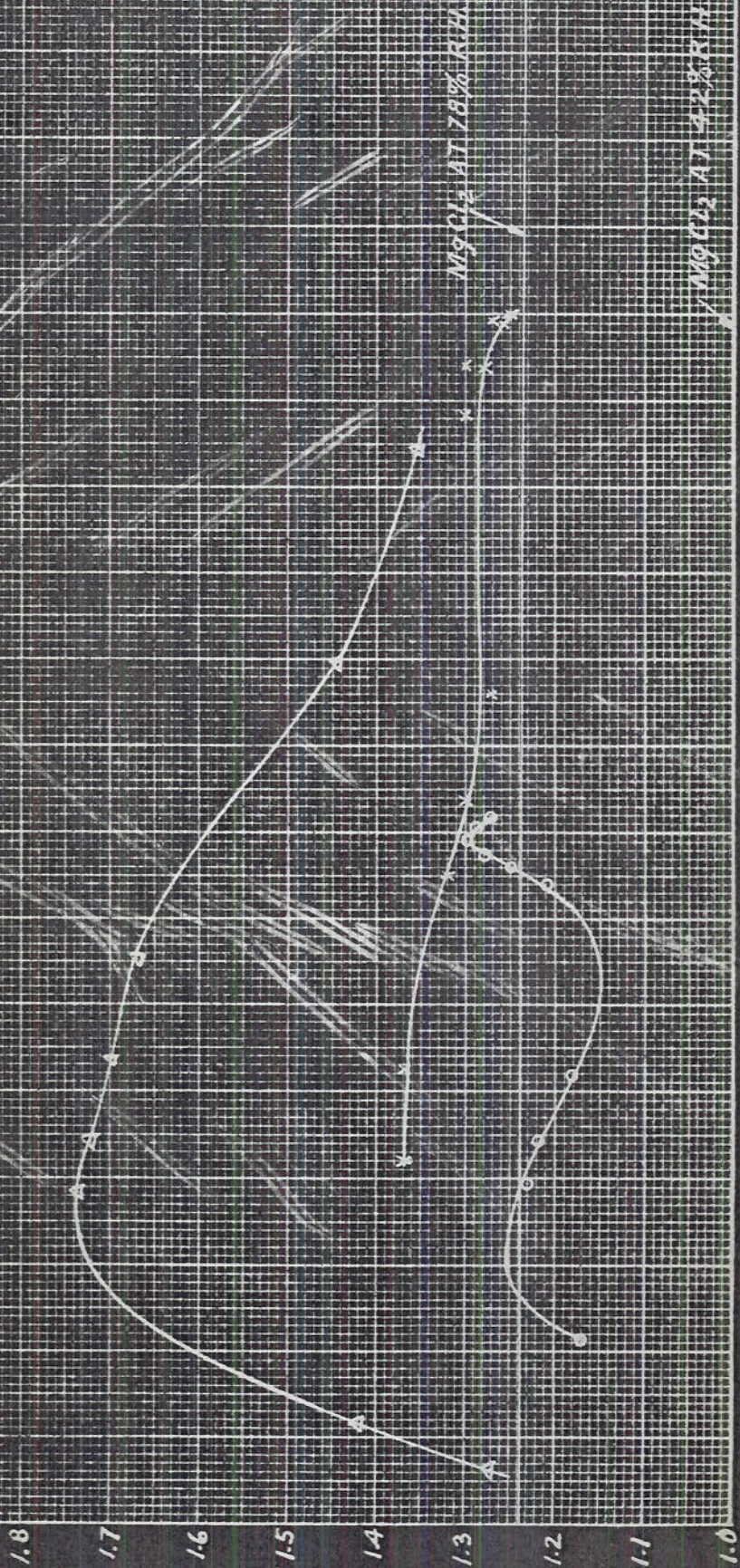
H₂O / CaCl₂
MCl₃ / CaCl₂

PLATE 4

122

MAGNESIUM CHLORIDE
 (ANHYDROUS - DOW CHEM. CO.)

Δ $MgCl_2$ AT 33°F AND 80% R.H.
 \times $MgCl_2$ " 100°F " 78% R.H.
 \circ $MgCl_2$ " 100°F " 42% R.H.



3

2

$H_2O / CaCl_2$