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Report

on

Investigation of Dehumidifying Agents
for Submarines and Closed Spaces in Ships -
Quicklime (Calcium Oxide) as a Desiccant

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ABSTRACT

This report analyzes the characteristics of quicklime as a drying agent for use in closed spaces aboard ship.

It is recommended that calcium chloride be employed as a desiccant in place of quicklime because quicklime has the following disadvantages:

- (a) It has a poor weight efficiency even if pure.
- (b) It is usually only partially effective because of the large percentage of impurities.
- (c) It absorbs carbon dioxide with a proportionate reduction in its dehumidifying power.
- (d) It is at best less economical than calcium chloride.

The characteristics of calcium chloride for such use have been given in NRL Report No. P-1234 and the details of methods of use will be reported shortly.

INTRODUCTION

(a) Authorization

1. This problem was authorized by Bureau of Engineering letter NPL4 (5-6-W8) of 12 July 1935.

(b) Statement of Problem

2. This report is a continuation of NRL Reports numbers P-1234 and P-1277. The investigation reported herein contains comparisons on the weight efficiency of calcium oxide with other drying agents, and the cost per pound of water removed, as compared with the other desiccants.

(c) Known Facts Bearing on the Problem

3. Quicklime is the oldest known drying agent, and in spite of serious defects is still widely used for the removal of moisture. For example, it is used in the Philadelphia Navy Yard for keeping the double bottoms and other closed spaces of decommissioned ships dry.

4. As stated in NRL Reports numbers P-1234 and P-1277, the weight efficiencies of various drying agents at different relative humidities can be calculated from data in the literature. These values for quicklime are compared with the same values for various other drying agents in the paragraph headed "Data Obtained." For lime the weight efficiencies were calculated by assuming that the quantity of water absorbed is that given by the chemical equation: $\text{CaO} + \text{H}_2\text{O} = \text{Ca}(\text{OH})_2$. This is essentially correct because the calcium hydroxide (slaked lime) formed is not hygroscopic. A negligible amount of moisture is absorbed on the surface of the calcium hydroxide.

(d) Theoretical Considerations

5. Aside from the fact that at best calcium oxide has a low weight efficiency, it has two other serious drawbacks. Since lime is prepared by igniting natural limestone or other lime containing carbonates, without any further treatment, the substance contains all the natural impurities. None of these will absorb water. Federal Specifications S.S.-Q351 of August 19, 1930, give the following specifications for quicklime:

On a non-volatile basis -	
Calcium oxide + magnesium oxide	95%
Silica, alumina, iron oxide	5%
Volatile substances -	
Carbon dioxide	Less than 10%
Type C quicklime (calcium)	
Calcium oxide	Not less than 75%
Type M quicklime (magnesium)	
Magnesium oxide	Not less than 20%

These figures show that, even using the best type of quicklime for drying (type C), we have a poor desiccant. On a non-volatile basis this need contain only 75% active material (calcium oxide), and if we consider that the lime before being reduced to non-volatile basis could contain 10% carbon dioxide, this would mean only 68% active material.

6. Probably not all of the quicklime delivered to the Navy has as low a calcium oxide content as this, but it could have and would still pass the Government specifications. These specifications were drawn up for lime for building purposes, where a higher calcium oxide content is not necessary, but it is doubtful whether markedly different specifications could be drawn up without causing an increase in price. A sample of lime which had been in use at the Philadelphia Navy Yard was analyzed, and proved to be type M lime, and highly inefficient.

7. The other drawback exhibited by quicklime is the fact that it absorbs carbon dioxide about as readily as it does water. When this occurs calcium carbonate is formed, and this substance has no drying properties. Thus any absorption of carbon dioxide renders part of the lime unfit for drying.

(e) Original Work Done at this Laboratory

8. The only original work done in this Laboratory on quicklime was an inspection of double bottoms and other closed spaces dried with quicklime, and an analysis of some of the lime which had been used. The ships inspected were decommissioned ships at the Philadelphia Navy Yard.

DATA OBTAINED

9. The quicklime used at the Philadelphia Navy Yard is placed in small flat wooden trays in the compartment to be dried or kept dry. The compartment is then tightly sealed, and opened only periodically for inspection. The trays are roughly 12"x18"x4", and contain several pounds of lime which lasts for a period of some months. When the lime gives evidence of having slaked from the absorbed moisture, a fresh supply is used. The condition of the lime is ascertained by seeing how crumbly it has become, as fresh quicklime is hard and will not break up readily in the fingers.

10. The compartment, so dried, in every case was in good shape and in no case was there evidence of moisture on the walls or an undue amount of corrosion. Lime, if used in sufficient quantities, is an adequate drying agent, but is not the most economical one.

11. A sample of the partly spent lime was taken from the USS DYFR and analyzed. It proved to be type M (magnesium) quicklime and very inefficient. The analysis of the lime, as obtained, follows:

Table 1

Volume - 1000 cu.ft.; temperature of room - 90°F.; initial relative humidity - 90%;
total water vapor in room = 13,311 grains.

	70	60	50	40	30	20	10
Final relative humidity							
Grains 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*
Quicklime	1.31	1.97	2.64	3.29	3.95	4.61	5.26
Cost of drying room -							
Calcium chloride at \$0.02/lb.	\$0.0032	\$0.006	\$0.010	\$0.015	\$0.022	\$0.032	\$0.06
Calcium chloride	0.03	0.009	0.015	0.022	0.033	0.048	0.09
Calcium chloride	0.05	0.015	0.025	0.037	0.055	0.080	0.15
Magnesium chloride	0.07	0.017	0.025	0.035			
Lithium chloride	1.00	0.195	0.31	0.53	0.75	1.14	2.10
Lithium chloride	1.25	0.244	0.387	0.66	0.94	1.42	2.62
Quicklime (90%)	0.006	0.013	0.018	0.022	0.027	0.031	0.036
Quicklime (60%)	0.006	0.020	0.027	0.033	0.040	0.046	0.054

* Extrapolated.

14. From this table it is apparent that calcium chloride at \$0.03 per pound is more economical as a drying agent than quicklime, which is 90% efficient down to relative humidities of 40%. The average quicklime is probably nearer 60% efficient than 90%, and under these conditions it would be more economical to use calcium chloride down to relative humidities of 20%. In practice it is seldom necessary to reduce the relative humidity below 30 or 40%.

CONCLUSIONS AND RECOMMENDATIONS

15. This report shows that calcium chloride is a more economical drying agent than quicklime, and that it is free from several of the disadvantages shown by quicklime. It is recommended that calcium chloride be used in place of quicklime wherever the air in closed spaces has to be dehumidified.

SUMMARY

16. This report discusses quicklime as a drying agent and compares the economics of dehumidifying air with quicklime and other desiccants.