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"METAL REUSABLE CONTAINER PERFORMANCE UNDER CONTROLLED ENVIRONMENTAL TESTING"

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Mr. McDermit was the Director of the Packaging Engineering and Development Branch of the U.S. Army Tank Automotive Command in Warren, Michigan. This presentation was made at the Fall 1970 meeting of the Packaging, Handling & Transportability Division of the American Ordinance Association (now the National Defense Industrial Association). Significant paragraphs are shown in bold type.

The Tank Automotive Command has very recently completed a study project intended to provide certain information relative to the performance of metal reusable containers. Project title and title of the final report is, "Comparative Environmental Tests of Selected Variables in Reusable Metal Shipping Containers." The final report is now in draft form and will be published shortly. A limited number of copies will be available for distribution. This study project was conducted under contract between the Tank Automotive Command and Ryco Engineering, Inc. in Warren, Michigan.

To avoid any misunderstandings as to the intent and objectives of this study, I will make it as clear and simple as I possibly can. This was not a research and development project. We were not attempting to prove or disprove whether container designs incorporating controlled breathing valves would perform adequately, or whether free-breathing containers were less adequate than the controlled type. Neither were we attempting to establish that in terms of storage life reliability the sealed, pressurized designs are superior to breather types. Our primary study objectives were to establish certain limited design parameters for controlled breathing type containers and to establish criteria for inspection and maintenance during storage for such container systems.

U.S. Army Tank Automotive Command has approximately 150 metal reusable container designs in existence. These are all, with one exception, the totally sealed, pressurized design. From the viewpoint of performance, there is no reason to change our designs. The pressurized containers have performed excellently and, when properly designed and fabricated, provide optimum protection under any and all conditions of shipment and storage.

Due to the pressurization requirements, these containers are excessively heavy. Our container-to-item weight ratio is approximately one-to-one and in some cases the container exceeds the weight of the item contained. In addition to the container weight, pressurization also influences design characteristics, which increases exterior cube of the container. In order to withstand the 15 psi test pressure and hold a 5 psi shipping and storage pressure such containers are usually rounded or elliptical in configuration.

Some time ago, after considerable study of the degree and direction of movement of containerized items in an elastomeric shock mitigating system, during which we found that the item never moved three inches, we adopted a rectangular configuration as our basic design policy. We were successful in reducing cube by approximately 25%. However, any potential reduction in weight resulting from reduced size was offset by the need to increase container body cross section. Heavier cross section is required to withstand internal pressure on the flat surface.

During one recent fiscal year, the Tank Automotive Command procured approximately 50,000 steel reusable containers. Using very conservative computation factors, we estimate that by reducing the weight of our containers by an average of 25% we could save in a comparable procurement year 4.25 million pounds of shipping weight. In carload lots, the rate for engines and transmissions to one destination is approximately $5.50 per hundred weight. The savings in weight would result in a transportation savings of $233,750 per year. We believe the potential of 25% weight reduction by use of lighter weight non-pressurized design to be reasonably attainable.

So, as stated earlier, our objective was to determine whether high or low pressure activated valves were most desirable and to establish criteria for control and maintenance of breather type containers during storage. It is also worthy of note that any criteria established as a result of this test will, without any initial adjustment for variations in climatic regimes, be applicable to 80% of our storage areas around the world. This will be discussed at greater length later.

The containers used in this test were of all steel construction and had been procured several years previously for another project. As originally procured, the containers were the free-breathing type, bolted top with a flat rubber gasket between the top of container and the flat lid. The containers were modified for this test by welding the tops to the containers and providing for end access. The containers were 80 inches in length, 24 inches wide, and 23 inches deep. Except for framing members, the containers were made of 10 gauge steel. Eight of these containers were used in the test.

Instrumentation used for this study consisted of a 24 channel Bristol Recorder; temperature and humidity monitoring were by hygroscopic humidity and thermistor temperature pickups. Sensors were manufactured by Hygrodynamics. Pressures were monitored by Computer Instrument Company bellows type sensors. The system scanned all channels once each six minutes. During the two years the study ran, approximately two miles of chart were produced; 4,204,800 data bits were recorded on the instrument charts. These statistics are not given for the purpose of impressing anyone but rather to point out a problem that was recognized at the beginning of the study. The scope of the contract and funding limitations (it was a fixed price contract) did not permit the manual review, comparative analysis, and extrapolation of data beyond the limited scope established by the contract. Had the system been designed to provide data in computer input form, we would have had a much more versatile program. Any studies of this nature that we conduct in the future will be so designed.

The sensing and recording system was designed to provide the following information:

1. Container internal humidity
2. Container internal temperature
3. Container internal pressure
4. Ambient relative humidity
5. Ambient temperature
6. Atmospheric pressure

In addition to the above system output, contractor's engineers were also required to periodically weigh the various desiccant charges and record gains in weight. The contractor was also required, through interpretation of the machine recorded data, to determine and record how many times the controlled breather containers breathed. We had originally planned to weigh the desiccant in the containers by use of load cells. Due to the limitations of these systems, this plan was abandoned.

Each of the eight containers was placed on test with one or more variables relative to the other containers on test. Briefly, the individual container systems were as follows:

1. Pressurized at 5 psi with molecular sieve desiccant.
2. Controlled breather, +2 and -1 psi valves. Silica gel desiccant.
3. Controlled breather, +2 and -1 psi valves. Silica gel desiccant. Insulated internally with 1" polyurethane foam, 1 lb. density.
4. Controlled breather, +1 and -1/2 psi valves. Silica gel desiccant.
5. Pressurized at 5 psi. Silica gel desiccant.
6. Free-breather. Molecular sieve desiccant.
7. Free-breather. Silica gel desiccant.
8. Free-breather. Silica gel desiccant. Internally insulated with 1" polyurethane foam, 1 lb. density.

The test site was adjacent to the contractor's engineering facility on 9 Mile Rd., in Warren, Michigan. The first location selected by the contractor was rejected because it did not permit proper exposure of the containers. The area selected provided good security but it would only provide a few hours of direct sunlight per day, having a high shrubbery wall on one side and the building wall on the other. The next location selected was later abandoned by the contractor because his studies showed that containers would be affected by heat and the shadow of the building. The final selection was an area near the center of the company parking lot. This area was enclosed within a six foot cyclone fence with a locked gate. Figure 1 is an artist's view of the test site. Cables from the various sensing devices were run overhead to the rear of the main builiding. The recording instrument was indoors in the main building.

FIGURE 1. TEST SITE

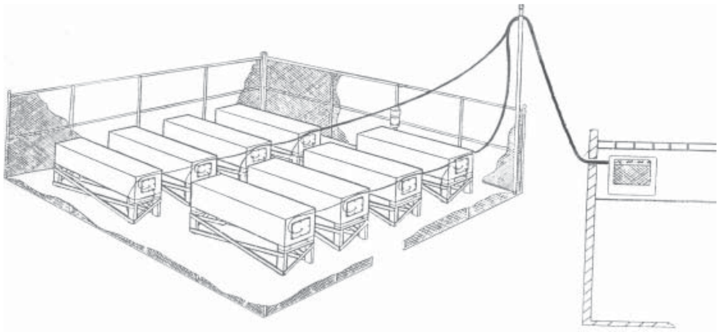


Figure 2 shows the system diagram of the various container configurations and sensing channels. This includes the eight containers and the ambient humidity, temperature and atmospheric pressure sensors.

FIGURE 2. CONTAINER ARRANGEMENT AND CONNECTIONS

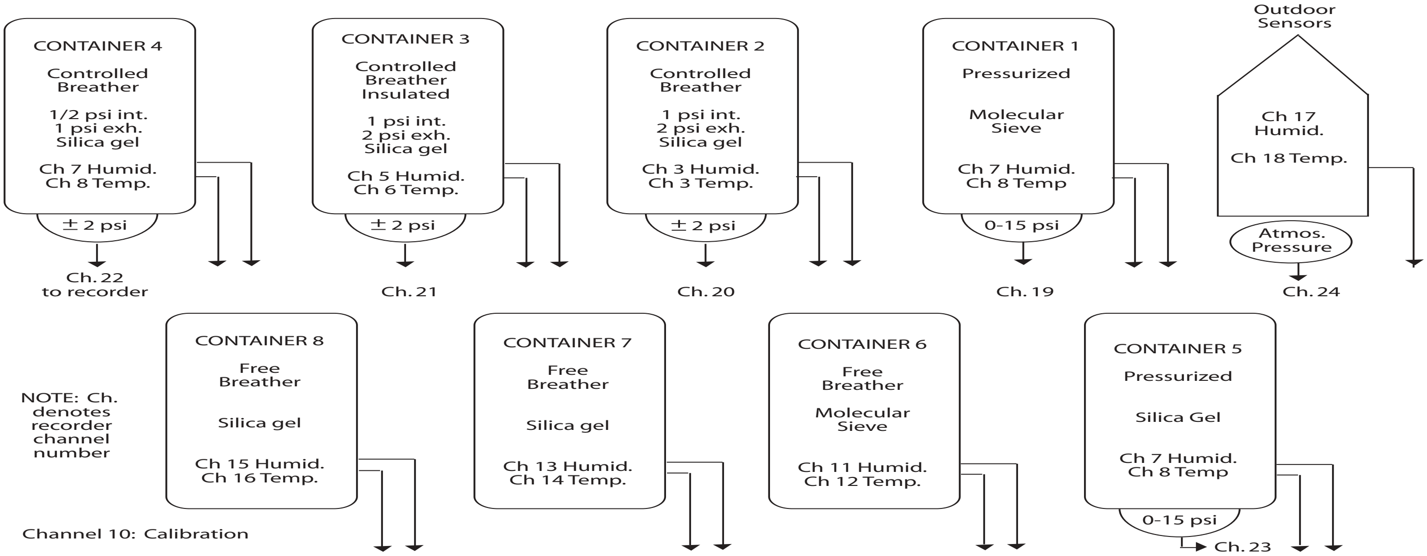


Figure 3 shows one of the containers on its stand and the location of cable connectors and valves.

FIGURE 3. CONTAINER EXTERIORS & MOUNTING STANDS

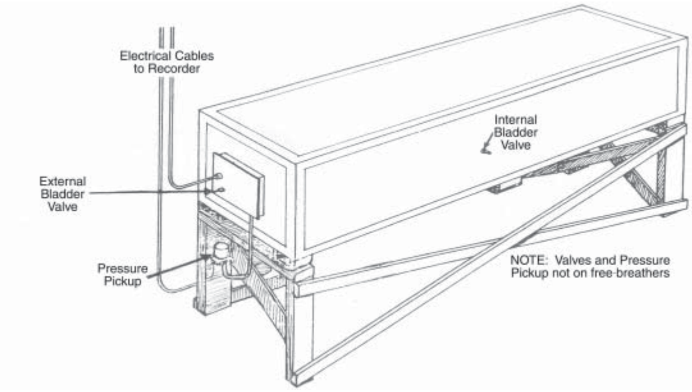
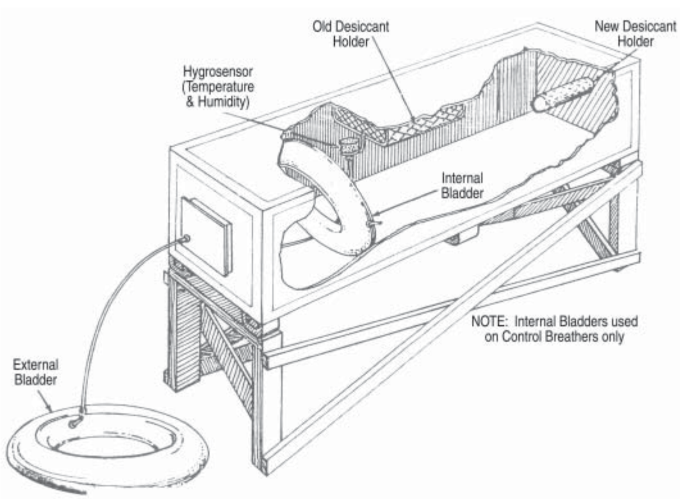


Figure 4 is a cut-away view showing the pressure equalizer system used. It also shows the position of the desiccant holder and sensing element. The pressure equalization function was only used on the controlled breather type containers. In order to minimize the effect of removing the desiccant holder and valves each time the desiccant was weighed, an attempt was made to bring the internal pressure differential to zero before opening.

FIGURE 4. CONTAINER INTERIORS AND PRESSURE EQUALIZING BLADDERS



I must caution anyone who may read the official report to do so with certain reservations. We anticipated at the start of the study that in all probability our findings would reveal many areas where additional study would be useful and profitable. As we anticipated, this has been the result. The answers required by the study were obtained. We are very satified with the results. The questions raised by observation and recognition of certain side effects and phenomena appear to have impressed the engineers conducting the test to the point where discussion of potential studies overshadow the good results attained. The matter of future study recommendations will be covered later.

As stated previously, we wanted to determine by means of this study how efficiently breather type containers function, and how efficiently such systems worked in comparison to each other. The data we have developed will be used as guidance in the design effort and in technical publications, such as Storage Serviceability Standards.

In regard to the findings, I am sure that many will say that much of this is not new. To this I can agree without argument. However, there has been very little recorded data available which was both comprehensive and comparative. To this extent, we believe the study is moderately unique.

Both the free-breather and the controlled pressure breather containers performed far better than we expected. Our previous experience with free-breathers did not give us any basis for expecting more than six months useful life for the desiccant charge. All three of the free-breathers remained in control relative to average relative humidities per day for 13 to 19 months. While we retain our previous conclusions relative to the free-breather principle, the results of this study demand that we have an open mind for future consideration and further study. At the present time, however, we have no intention of going to free-breathers. The following selected charts graphically depict our recorded experience with the free-breather containers during the two year test. These individual charts are plotted averaging some of the data recorded every six minutes by the instrument system. Figures 5, 6 and 7 show the ambient relative humidity and internal relative humidity for containers 6, 7 and 8. Container 6 is shown as a line of short broken dashes; container 7 as a solid line; container 8 as a line of dashes with two dots.

FIGURE 5. CONTAINERS 6, 7 AND 8 HOURLY HUMIDITIES FOR SEPT. 4-6, 1968

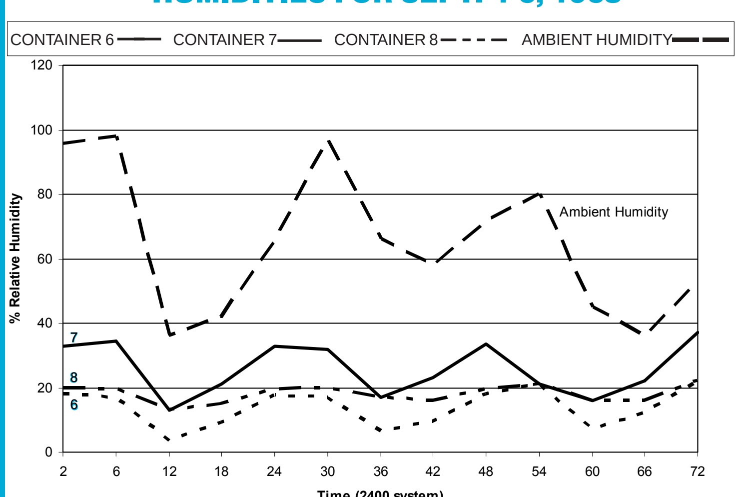


FIGURE 6. CONTAINERS 6, 7 AND 8 HOURLY HUMIDITIES FOR JAN. 26-28, 1969

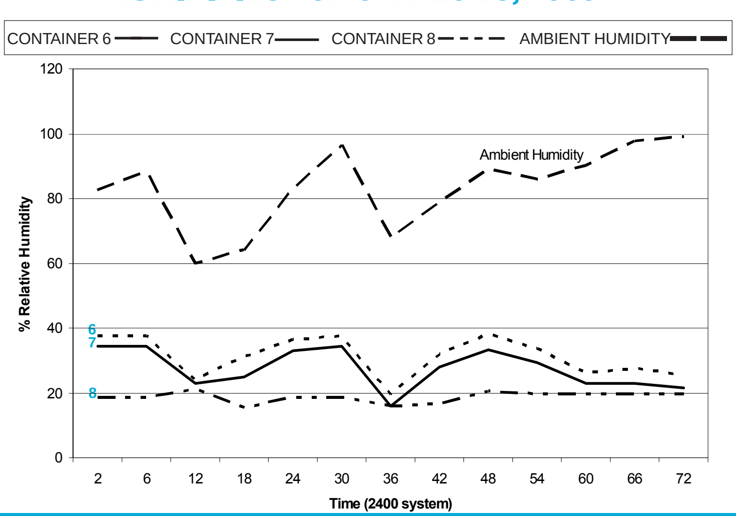
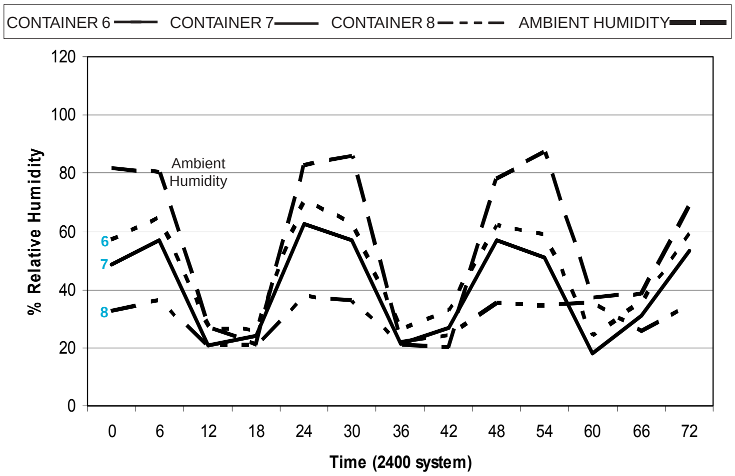


FIGURE 7. CONTAINERS 6, 7 AND 8 HOURLY HUMIDITIES FOR JULY 1-3, 1969



This is stressed to alert you to the fact that on later graphs in the report the identity is changed. Container 6, which was desiccated with molecular sieve, remained in control for 13 months. This was the shortest period of the three free-breathing containers. At first glance, this could be a minus value for molecular sieves. I am not accepting that conclusion. Pending further analysis, we are attributing the shorter life to the more aggressive moisture "grabbing" characteristic of the molecular sieves. In free-breather type applications this could be a plus value characteristic. We will discuss molecular sieves at greater length later. Container 7, which was desiccated with silica gel, stayed in control for approximately 14 months. Container 8, desiccated with silica gel and insulated with 1" of polyurethane foam, was good for 20 months.

In regard to the controlled pressure breather containers, I have very little to show you in the form of relative humidity graphs. The reason for this is quite simple, although somewhat unbelievable. The containers, after drying out internally within approximately 30 days, never got off zero relative humidity (RH) during the entire period of the test, except in the case of container 4 which did show a slight rise for one period after a year and a half.

In regard to this continuous 0% RH, we were very dubious and as a result, when the test was completed and dismantled, I had all instrumentation brought in to our Calibration Laboratory for a complete check-out. Calibration results indicated that acceptable accuracy was not present below 16% RH. So whenever I or the report refers to 0% RH, it must be taken as any percent from 0 to 16. We do know that the container atmosphere, with one exception noted, stayed within this low range throughout the entire two year test. If the relative humidity records were the only data obtained, we would be in trouble in making a decision between systems. However, breathing cycles and weight gain of desiccants are variables recorded and evaluated during this study.

It will be recalled that we had three controlled pressure breather containers on test. Container 2 was controlled at -1 psi and +2 psi and was charged with silica gel desiccant. Container 3 was the same as No. 2 except that the container was insulated. Container 4 was controlled at -1/2 psi and +1 psi. This container also had silica gel desiccant. I regret that we did not use molecular sieve in one of the controlled pressure breathers. With the variables involved, we are able to assess the difference between the systems.

Frequency of breathing was one of the variables to be evaluated. Before the test was actually started, we found that we were in some trouble in relation to accurately determining when the valve opens and when it closes. When we first established the parameters for the study, I wanted monitoring the valve action electronically recorded. Our Instrument Laboratory decided that this would be complex, expensive and subject to high maintenance requirements. It was considered (on a theoretical basis) to be unnecessary inasmuch as we would be sensing on internal pressures and this should signal valve action by pressure change. In theory this is so—in practice the way the available valves function, it is not so good. Table I of the report gives a monthly summation of the frequency of breathing for containers 2, 3 and 4.

TABLE I. CONTAINER BREATHING FREQUENCIES

MONTH	CONTAINER NUMBER					
	4		3		2	
	IN	OUT	IN	OUT	IN	OUT
Jan. 1968	9	0	1	0	1	0
Feb.	6	6	0	0	0	0
March	13	22	0	0	0	0
April	22	21	0	0	0	1
May	18	20	0	0	0	2
June	10	31	0	0	0	4
July	14	35	0	0	0	0
Aug.	12	39	0	0	0	0
Sept.	12	14	0	0	0	0
Oct.	9	8	1	0	1	0
Nov.	4	1	0	0	0	0
Dec.	7	2	1	0	2	0
1968 TOTAL	**136**	**199**	**3**	**0**	**4**	**7**
Jan. 1969	6	7	1	0	1	0
Feb.	2	4	0	0	0	0
March	8	17	3	0	0	0
April	13	17	0	0	0	2
May	16	24	0	2	2	1
June	14	13	0	0	3	1
July	9	22	0	1	0	0
Aug.	12	24	0	0	0	0
Sept.	9	12	0	0	0	0
Oct.	6	6	1	0	1	1
Nov.	2	1	1	0	1	0
Dec.	2	3	1	0	1	0
Jan. 1970	3	3	1	0	1	0
1969 TOTAL	**102**	**153**	**8**	**3**	**10**	**5**
1968-69 TOTAL	**238**	**352**	**11**	**3**	**14**	**12**

Container 4 breathed in 238 times and exhaled 352 times during the two year test. Container 4 was the low pressure container -1/2 psi + 1 psi. Container 3 breathed in 11 times and exhaled 3 times during the test. This was the insulated breather with -1 psi +2 psi valves. Container 2 inhaled 14 times and exhaled 12 times. Because of the fact that cracking action of the valves is not a precise function of opening at an exact pressure and then dumping the pressure differential in a prescribed period of time, we suspect that breathing took place without detection.

We obtained specially manufactured valves that were supposed to be precision type. We found, however, that the valve action was a partial opening with gradual dissipation of the pressure differential. Minute pressure change over a considerable period of time (1 or 2 hours or longer) was difficult to determine from the recorder charts. We also suspect that, at least in the case of the higher pressure valves, that breathing was prevented by the container adjusting itself physically to the pressure change by "oil canning." This is a phenomena that needs more study as a potential design feature.

In regard to desiccant weight gains, which for the purpose of this study we equate with water, the study has produced some interesting data. Figure 8 plots the desiccant weight gain for containers 2, 3, 4, 6, 7 and 8. Containers 1 and 5 were the pressurized containers. The silica gel and molecular sieve in containers 1 and 5 were only weighed at the beginning and end of the two year test. It is noted at this time that at the start of the test 10 grams of free water were introduced into each container. Any weight gain recorded must be qualified by subtracting 10 grams from the total gain. It is also noted that, had this water not been added, pull down time would have been less than the 30 days we experienced. Including Nos. 1 and 5 pressurized containers, we had the following weight gains:

- Container #1: Pressurized, molecular sieves, at 27 months had gained 28.7 grams.
- Container #5: Pressurized, silica gel, at 27 months had gained 21.6 grams.
- Container #2: Controlled breather, 1 psi - 2 psi, silica gel, after one year, 21.10 grams; after 27 months, 24.80 grams.
- Container #3: Controlled breather, insulated 1 psi - 2 psi, silica gel, after 1 year, 32.69 grams; after 27 months, 41.40 grams.
- Container #4: Controlled breather, 1/2 psi - 1 psi, silica gel, after 1 year, 24.8 grams; after 27 months, 32.3 grams.

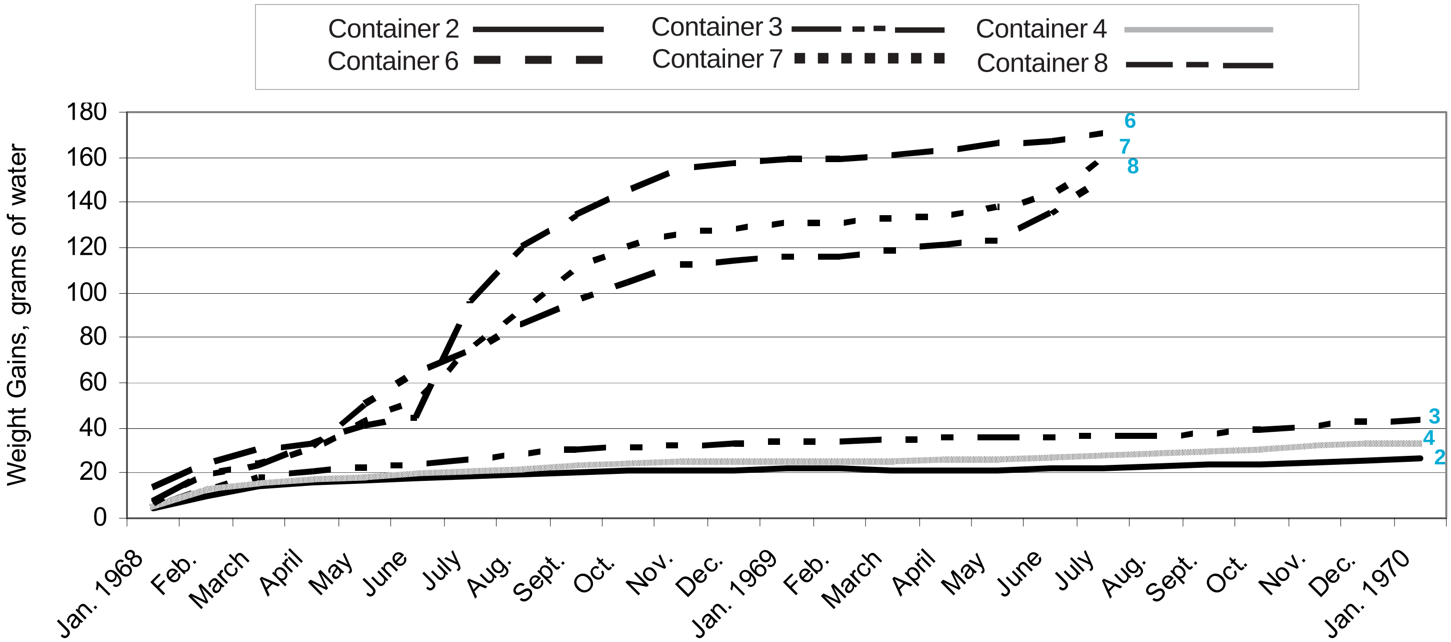
NOTE: Containers remained on test 3 months after expiration of contract. The contractor suggested that the test continue until warmer weather at his expense. We accepted. The 3 free-breather containers in 18 months gained as follows:

- Container #6: Free-breather, molecular sieve, after 1 year, 158 grams; after 18 months, 169 grams.
- Container #7: Free-breather, silica gel, after 1 year, 131 grams; after 18 months, 179.95 grams.
- Container #8: Free-breather, insulated, silica gel, after 1 year, 116 grams; after 18 months, 132 grams.

Desiccant was weighed on the following schedule: pressurized container at start and finish of test; free-breathers every seven days; controlled breathers every 30 days.

I cannot attempt to explain some of the seeming contradictions of these values. We have not completed our analysis of the data and, in some cases, complete analysis without further testing will not provide an answer. A good example is Container 4. This container, with the 1/2 psi - 1 psi valves, inhaled 224 times more often and exhaled 340 times more often than the next higher container. Container 4, however, had a desiccant weight gain of 32.30 grams against 41.40 grams for Container 3. One answer which suggests itself is out-gassing of the moisture during breathing cycles. The out-gassing theory can also explain

FIGURE 8. DESICCANT WEIGHT GAINS FOR 1968-1970



the greater weight gains of the molecular sieves. In addition to its demonstrated ability to pick up water faster, in greater quantity its higher reactivation temperature could result in retention of the water it has captured. This is an area which we hope we can study further in the very near future. Desiccant weight gains by percentage are as follows. All figures are approximate.

- Container #1: Pressurized, molecular sieve, 3%
- Container #2: Controlled breather, 1 psi - 2 psi, silica gel, 3%
- Container #3: Controlled breather, 1 psi - 2 psi, insulated, silica gel, 5%
- Container #4: Controlled breather, 1/2 psi - 1 psi, silica gel, 4%
- Container #5: Pressurized, silica gel, 2.5%
- Container #6: Free-breather, molecular sieve, 17%
- Container #7: Free-breather, silica gel, 20%
- Container #8: Free-breather, silica gel, 15%

In regard to our conclusions, we have arrived at the following:

a. We can convert to a design policy of controlled breather containers without imposing any significant additional workload on the supply system. We will initially establish a shelf life limit of five years without necessity of recharging desiccants in all climates except marine-tropic climatic regimes. in such, climates we will limit shelf life to three years until storage experience is gained.

b. On the basis of our study we will in all probability use the 1 psi - 2 psi valve.

c. We believe that molecular sieves may be the desiccant to use in breather systems but feel that some additional study and analysis is required.

d. All new designs for Tank Automotive Command items will be controlled breather containers.

e. Our experience with the instrumentation used on this test has done nothing to create confidence in systems using electronic humidity sensing devices. We were confronted with problems of air pollution which seriously corroded the sensing elements. It was necessary to repair and replace the probes a number of times during the study. While these devices are not used relative to containers, we have been and are involved in dehumidification systems for ships and structures. This matter of corrosion is discussed at length in the report.

In respect to matters requiring further study, we believe the following matters to be of sufficient importance and potentially beneficial to require study in depth.

a. Desiccant formulae. Because of our findings during this study, we are convinced that desiccant formulae requires overall review and revision. We believe the formulae used results in excessive use of desiccant at least for some types of packs, such as pressurized metal containers. We need to establish new formulae for breather type containers and for use of molecular sieves. This is an area requiring additional study and investigation.

b. Further study is needed relative to the effect of sunlight and shadow on breather containers. Our analysis of test results to date indicate that you can expect longer shelf life from a controlled breather container and from free breathers when they are protected from direct sunlight. In simple terms, a group of containers in outdoor storage will have some containers in the inner rows protected on all sides from sun, wind, rain, etc. The life of the inner rows will be considerably longer than those in the outer rows and tiers.

c. The "oil canning" phenomena also needs further study. This study should be made in connection with additional study on valve pressures and container strengths required for breather systems. The primary constraint against container weight after adoption of the breather principle is not pressure—it is requirements for stacking strength. If design advantage can be taken of the ability of the container to adjust itself to pressure differentials, it is questioned whether balanced pressure valves are required.

d. Self-reactivation out-gassing is another phenomena for study and development of controls that will make this a design feature of breather systems. We know (although our contractor apparently did not) that this is no new discovery of principle. We are familiar with and have had successful tests using the Solar Radiation Breathers developed by Davidson Chemical Company some years ago.

In summary, we are not implying that we have made any startling discoveries or technological break-throughs. No new scientific principles have been developed. We do feel, however, that we have attained much good data on which to base our future designs and storage controls. As we have the opportunity for deeper analysis of the data obtained, we have no doubt that we will be further enlightened.

Thank you for your attention.