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EVOLUTION OF ENVIRONMENTAL TESTING

by

R S Hooper

May 1959

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EVOLUTION OF ENVIRONMENTAL TESTING

Some weeks ago at a division meeting several of us were first talking about the expanding role of our testing laboratory and its facilities, and we somehow began talking about future plans and possibilities. We, more or less automatically, assumed that any further expansion would be directly proportional to the number of new environments that we would be called upon to simulate. So we considered first those new environments which are getting so much publicity today. For one thing, Rear Admiral Rawson Bennett, Chief of Naval Research, and Commander George F. Bond, Assistant Officer-in-Charge of the U. S. Naval Medical Research Laboratory, have both given talks about the importance of the environment under the sea. Besides the many obvious military implications of underwater environment, there has been much discussion about an even more important implication, the possibility of finding a better access to a presently untouched food supply for the earth's ever-increasing population.

Of course, we also talked about that very popular topic, the onrushing explorations of the Space Age, with its so-called "hyperenvironments." The general feeling was that the environmental laboratory should perhaps be gathering, and gathering now, information on the nature, the methods of simulating, and the effects of such conditions as ultrahigh temperature, extremely high vacuum, high-density radiation, zero gravity, meteors, ionized gases, and so forth. We began to see the space man's vehicle being made possible, and then ever more reliable, partially by the work of "hyperenvironmental" laboratories. From here, you might well imagine, it was not hard to take another step further in fancy, to where we had to face more advanced problems awaiting the "super hyperenvironmental" engineer working with the astronomers and astrophysicists studying the environments associated with, and peculiar to, various planets far removed from planet Earth. I will let your own imaginations supply the type of problems, human endurance and so on, that we came up with.

I will admit that our conjectures bordered, at times, on science fiction, but we finally got back to earth again and realized, perhaps even more clearly, that we have some little bit to do before we in environmental work adequately understand our own mundane surroundings.

When we see a professional meeting of the size of the one this year, and measure it against the feeble beginnings in early 1953--when environmental engineering as such was still somewhere between design engineering, refrigeration engineering,

instrument engineering, and so forth--we realize that there has been phenomenal growth in this new engineering profession. But a profession expanding this rapidly must take care, or we will be going much in the manner of our division discussion. For the mere advent of our new space environments does not guarantee a phenomenal new growth of our profession--not necessarily--not without some planning. I think that we should take an occasion to pause now and then to review our progress and to analyze that progress in terms of our future plans and responsibilities. By so doing, we may be able to discover weaknesses that can be eliminated or strengths on which we can capitalize further.

Today, for my part, I wish to discuss briefly the progress over the last 7 years or so of our environmental laboratory at Sandia Corporation. By so doing, I hope to discuss some of the general problems that many of us have seen during the formation and growth of the environmental engineering profession. The mission of Sandia Corporation is to accomplish the ordnance engineering for the AEC's Nuclear Weapons Development Program. Many unique and complex electromechanical and electronic components are designed and tested in accomplishing this mission. The very nature of the product designed by Sandia Corporation suggests the need for a uniquely reliable system. The test work must then include much environmental testing to help assure this high reliability. During the past 7 years, as you may imagine, environmental testing has expanded at Sandia. These changes have occurred in the following areas which, though not necessarily independent of one another, should serve as a useful basis for this discussion (see Figure 1):

1. The increase in equipment required to simulate an ever-increasing number of environments.
2. The evolution of the responsibilities of the environmental engineer and his technical assistants.
3. The realization by the company that environmental testing is an art, and thus requires much experience, plus study and observation, and skill in performance.
4. The changes in the size of the organization in its structure and its duties.

In order to demonstrate the first of these four areas, let us look first at the situation at our laboratory at Sandia in the early 1950's, somewhat before the formation of the IEE and somewhat prior to the recognition by Sandia management of environmental engineering. The high- and low-temperature equipment and humidity

closets then required for components evaluation were readily available in each area that might need to do test work; for example, divisions responsible for design, quality control, production inspection, and so forth. Figure 2 shows some of the various groups at Sandia which require evaluation work in the various phases of the design and development of a product.

Now, the meager test equipment these organizations had in their respective areas was but the forerunner for much new required equipment--larger combined temperature and altitude chambers, shock test equipment, and vibration tables. Those purchases caused a need for a centralized location to avoid the expense of duplicating this more complex equipment, and this centralization of equipment was the beginning of the Environmental Test Laboratory at Sandia Corporation. Here, for example, is what was then our most complicated piece of test equipment--a small vibration machine, shown in Figure 3.

Rather than to go through a tedious chronological evolution of the expansion of our facilities, I will use Figures 4 through 16 to illustrate the changes in the various areas of environmental simulation required by Sandia. Figure 4 summarizes these changes in shock test and acceleration test facilities, and Figure 5 in temperature test and vibration test facilities.

For further example, Figure 6 shows one of our first shock testing facilities, and Figure 7 shows the old faithful sand box. A later development in our shock facilities is shown in Figure 8. This is a 450,000-pound force shock cord actuator. Figure 9 shows our 26-inch air gun, which is a 1,600,000-pound force testing facility. And a final shock test facility, a 300-foot drop tower, is shown in Figure 10.

In acceleration testing we have increased our facilities from a simple 6-foot acceleration, as shown in Figure 11, to a rocket acceleration facility shown in Figure 12, and finally to the hydraulic equipment shown in Figure 13. This machine has a maximum speed of 140 rpm and can take 10,000 pounds to as high as 50 g's. In temperature testing, one of our newest facilities is that shown in Figure 14. Besides the changes in equipment, we note also the many requirements we have had for new facilities, such as the dust chamber (with a working volume of 1600 ft³), the salt-rain chamber shown in Figure 15, the explosive chamber, acoustical vibration facilities, extensive static jiggling facilities, radiant heating facilities (which will be covered in another paper by Mr. Barber, of our organization), and so forth.

Starting with a small wooden building, we have expanded into the main building as shown in Figure 16, and to 14 other buildings in three different Corporation areas.

However, this centralization of equipment did not necessarily include centralization of environmental knowledge or even of all of Sandia's testing operations. The areas doing test work continued to test with their own facilities and used the test laboratory only when they needed larger facilities; the environmental engineer's responsibilities were only to place the components into the environments and to perform very routine test measurements or, as part of a supporting group, to buy the equipment, check it out, and look into the few complex instrumentation problems that came up.

Let us look, now, at the second area of change and see how the responsibilities have changed for the environmental engineer.

As I have said, by the early 1950's the environmental laboratory had come into being. Large equipment had been centralized but knowledge and testing had not. The test engineer had to prove the necessity for centralized tests and standardized test philosophies. This was done in two different areas.

On the one hand, for more efficiency, the evaluation organizations realized the benefit of having ever more of the component functional evaluation tests done for them by the testing group. People having components tested late in a production stage found it useful to have the test laboratory assist them in test planning by telling them the testing history of the particular component at prototype. This has developed into an important feedback system to design whereby the environmental laboratory records and maintains permanent records of tests and test sequences, failures, causes of failures, and so forth.

On the other hand, other organizations also began to realize that even the simple environment of, say, temperature had to be properly measured and its effect properly understood. Other environments such as sand and dust, salt fog, acceleration, etc., were being studied, and again it was realized that no such environment could be considered simply, nor could the effects of the environment always be easily interpreted. So we began to develop two types of experts for different functions; those who specialized more in the components were assigned more of the test planning and component evaluation, and those who specialized in the nature and effects of the environment were asked to serve more as the consultants on special problems and in the standardization of testing procedures.

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In order to unite these two groups, we at first formed technical committees where problems were discussed, assignments were made, and general information was exchanged. One of the first accomplishments of these committees was the publication of a "Vibration Guide," which set down underlying test philosophy and, wherever possible, standardized test procedures and instrumentation. Another accomplishment was a general testing specification to be used by other testing laboratories who would be called upon to test Sandia's products. This was at least an effort to standardize testing procedures between test laboratories.

Since the environmental engineer now performed some engineering activity, the group of technicians who assisted the engineer in the more routine portions of his assignments grew in number and stature. An engineer might have, for example, one, two, or three technicians directly assigned to him. A training program was set up for these technicians under the direction of a senior test engineer. The technician was taught the underlying physics of the environments, the methods of measuring and simulating them, and the deleterious effects that might be encountered in various instances.

Let me give you an example of a recent, though not yet typical, engineering assignment to illustrate the environmental engineer's functions and responsibilities now at Sandia. Let us presume that a new electromechanical component or system is being developed. Early in the problem, a test engineer is assigned to the development group. His responsibilities include assisting in the planning and coordinating of all environmental tests here and at the manufacturing source, and helping to write the required test specifications. He has a desk in the development group area and attends all the pertinent design conferences. Figure 18 summarizes this change in responsibilities and duties of the environmental engineer. We have noted that our test engineers have developed into two technical types.

As we have seen, as the job of the environmental engineer became more complex, and as the engineer himself became more experienced, the necessity of having one laboratory, in some way, be responsible for every environmental testing activity became more apparent. The fact that environmental testing was an art requiring the skills and experience of those who now called themselves environmental engineers was clearly demonstrated. In Figure 19 we note again, in a semiquantitative way, how this change came about, for the company's attitude changed somewhat. Initially it was thought that anyone knew all about environmental work. We are now approaching cautiously a more knowledgeable position. And the organization,

of course, grew and changed with the changes already mentioned, from its early beginnings, when it was composed of a group of 28 people. This organization evolved as the new areas of activity evolved. The organization shown in Figure 21 now allows room for the growth of environmental experts and also for the growth of a strong test liaison group who now do much of the planning, testing, and specification writing during evaluation. Engineers from this liaison group are assigned to various development organizations. They help plan the test work, see that it gets performed in the appropriate area laboratory, and issue all final reports.

Changing from the simple necessity of having high-temperature and low-temperature chambers accessible to evaluation organizations to a laboratory equipped to handle tests called out in the many testing specifications demanded a large investment. Initially, the subtle complexities of the so-called simple environments of temperature, low pressure, vibration shock, centrifugal acceleration, humidity, etc., were not widely appreciated. Many of the component development organizations kept their own limited test equipment, despite the centralization efforts of the environmental laboratories. Those in the main laboratory had full-time environmental test work. They studied new equipment and instrumentation and looked at the environment critically.

As a result, when the inevitable disagreements about test results occurred between the laboratory and other areas, we were usually on solid ground, and the faulty calibration or interpretation, or what have you, could usually be readily demonstrated. Now, some years later, we see the environmental laboratory approaching control of all such testing activity at Sandia, or any place in the country where our test work is done. All of the present environmental tests, once controlled and planned and studied in a host of areas, are now being centralized under environmental testing.

Now that I have had the opportunity to go over with you the progress of the environmental laboratory at Sandia Corporation, we might look at this progress in terms of what lessons we might learn for the future. If I have been successful in showing you anything, it seems to me that it is this: the growth of environmental engineering at Sandia and, of course, elsewhere has been in response to a definite need. When we became aware of the complexities of environmental testing and the interpretation of that testing, our organization became unified. We were asked to assume more responsibilities, we gained new stature, and we became larger. This is all to the good.

But if we can, after our backward glance, look forward to our hoped-for role in the future, we can perhaps predict needs before they occur, and thus not have so much "catching up" to do--the type of "catching up" we had to do in the past.

In discussing these various areas of change, there were at least three underlying activities that were important in causing the changes. Hence, they should also be important to any plans for future expansion.

Use of Test Information

Test information for a feedback system to design is used so that failures of components that occurred during environmental tests can become better categorized, filed, and then subjected to frequent reference during early design. The exchange of such data between test laboratories would be useful. We have developed a simple code to report the test history of a major component. We use a form similar to that shown in Figure 17. The test data are entered, in the sequence performed, as shown in Data Entry No. 007, 008, and 009. Each number entered indicates either a particular functional test or a particular environmental test. For example, the number "4" indicates a certain functional test which, when followed by the letter "S" indicates that the test was satisfactory. The number "8" followed by a comma and a number "4" indicates the unit was next given a functional test during a +160°F temperature exposure. The computer available can then sort rapidly all items that passed or failed a particular test or sequence of tests or indicate rapidly the test history of a certain type of component. We will also have an accurate record of what information, such as reports, memoranda, letters, etc., is available for detail study. A more comprehensive test history program has since then been set up by the reliability group at Sandia. Our test laboratory will contribute to and use this facility.

The Formulation of Testing Procedures

Many areas of activity are still asking for tests on similar components to similar test specifications; but the differences in interpretation and in test procedures by various groups make environmental testing look unduly sloppy at times. Testing may indeed be an art, but there are definite orderly approaches to standardize test procedures that should be explored. We have recently, as noted, published a vibration guide and a first draft of a General Test Method to be used internally and at the various outside laboratories that may be doing testing for Sandia.

Systematic Study of the Environments

We at Sandia, and we in this organization, must, I think, look at the "hyper-environments" realistically in order to relate ourselves to the present technical

problem. These environments are now being studied in many different areas by different groups: the upper-atmosphere physicists, the meteorologists, the thermodynamicists, and so forth. Will environmental testing someday emerge again as an independent engineering entity from all those areas presently studying the hyperenvironments? What needs will we be required to satisfy? What will our responsibilities be? And what will our functions be? What training program will we need? It seems to me that we need some immediate planning, perhaps by a group assigned to the project of Advanced Environmental Studies. It is hoped that our various laboratories can and will allow both the organization and the time for such a group.

We feel that both our continued ability to perform our functions satisfactorily and our continued expansion may depend on the success of our united efforts in each of these areas.

1. Increase in Facilities Required to Simulate New Environments
2. Evolution of the Responsibilities of the Environmental Engineer
3. Acknowledgment that Environmental Testing is an Art
4. Size, Organization, and Duties of Laboratory Personnel

Figure 1. Areas of Change in Environmental Testing at Sandia

Organization	Phase				
	Bread-board	Proto-type	Early production	Production	Field
Systems development					
Component development					
Mtl's evaluation Production evaluation					
Quality control Production evaluation					
Inspection and receiving					
Quality assurance					

Figure 2. Organizations which Require the use of the Environmental Laboratory during Various Phases of a Program

Figure 3. High-Frequency Vibration Testing Equipment

526 011

Shock Test Facilities

	Previous	Present	
Number of facilities	5	15	
Maximum weight	150 lbs	2000 lbs	18,000 lbs
Maximum velocity change	30 ft/sec ²	950 ft/sec ²	85 ft/sec/sec

Acceleration Test Facilities

	Previous		Present	
Number of facilities	1		4	
Load	1 lb	175 lbs	10,000 lbs	2200 lbs
Maximum acceleration	200 g's	2 g's	50 g's	200 g's

Figure 4. Increase in Shock Test and Acceleration Test Facilities

Temperature Test Facilities

	Previous	Present
Number of facilities	6	17
Maximum temp. (°F)	+160	+1300
Minimum temp. (°F)	-90	-100

Vibration Test Facilities

	Previous		Present	
Number of facilities	2		10	
Frequency range (cps)	4-2000	10-60	5-500	5-2000
Maximum static load (lbs)	10	1000	10,000	250
Peak blocked force (lbs)	25	25,000	25,000	5000

Figure 5. Increase in Temperature and Vibration Test Facilities

Figure 6. Ten-Pound Shock Test Facility

526 013

Figure 7. A 150-Pound Shock Test Facility

Figure 8. Shock Cord Acceleration

Figure 9. Sketch of the 26-Inch Air Gun Facility

Figure 10. The 300-Foot Drop Tower

526 017

Figure 11. Rotary Accelerator

Figure 12. The Rocket-Powered Centrifuge

526 019

Figure 13. The Hydraulic Centrifuge

Figure 14. Climatic Chamber

Figure 15. The Salt Spray and Rain Chamber

526 022

Figure 16. Main Building of the Environmental Test Laboratory

TEST REPORT

IDENTIFICATION

SHEET 1 OF

ITEM			SERIAL DESIGNATION		Date	Test Code
X	Prefix	Number	Suf	Mfg. Code	Serial No.	Code
Data Source		Lot No.		Mfgd. to Dwg.		Part (Stock) No.
				Number		Iss
				Number		Suffix
Test Spec.			Purchase Order		Report Form No.	
Prefix	Number	Iss	Prefix	Number	Suf	No. Resp. Div.

To be Filled by EDP Div.
Last Entry No. Used
in Describing Test
Conditions
Last Entry No. Used
for Data

TEST DATA

Data Entry

Numbers → 001

002

003

004

005

006

Test Date			Test Purpose		Reporting Division		Disposition					
Mo.	Day	Yr.										
007			008		009		010		011		012	
0	4	S	0	8	,	0	4	S	1	0	7	0
013			014		015		016		017		018	
019			020		021		022		023		024	
025			026		027		028		029		030	
031			032		033		034		035		036	
037			038		039		040		041		042	
043			044		045		046		047		048	
049			050		051		052		053		054	

Signature

Div.

Figure 17

586 24

Figure 18. Changing Responsibilities of the Environmental Engineer and His Laboratory Assistants

556 025

Figure 19. The Change in Attitude Toward Environmental Testing

Figure 20. Early Organization of the Environmental Laboratory

526 027

Figure 21. Present Organization of the Environmental Laboratory