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PROPOSED STANDARDS DESCRIBING AND ESTIMATING LEAKS IN AEROSPACE HARDWARE

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ABSTRACT

This report presents the results of a study undertaken to establish a standard nomenclature for missile plumbing leaks as found with liquid leak detection solution. This standard is needed so that an observed leak can be described quantitatively in a manner understood by all personnel involved in inspection, testing, and evaluation.

Fitting leaks are divided into two types, threaded and flanged, and each type is divided into three classes according to standard cubic inches per minute.

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TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

TECHNICAL MEMORANDUM TM X-53692

PROPOSED STANDARDS DESCRIBING AND ESTIMATING LEAKS IN AEROSPACE HARDWARE

SUMMARY

This work was undertaken to establish a standard nomenclature for missile plumbing leaks as found with liquid leak detection solution, so that an observed leak can be described quantitatively in a manner understood by all personnel involved in inspection, testing, and evaluation.

Joints were separated into two basic types, threaded and flanged. Leaks in each type were further divided into three classes. Testing verified the validity of these divisions and established flow ranges for each.

Complete descriptions of each type and class are contained in the appendix.

A. INTRODUCTION

Much difficulty has been experienced in the past when one person has attempted to describe a leak (found with liquid detectors) in terms that are meaningful to another. Terms such as fuzz, fizz, foam, blowing, and spitting are in common use without common meaning, and with no real quantitative significance. Therefore, this work was undertaken to establish standard nomenclature with realistic quantitative meaning.

Hardware was procured, tested, and studied and it was found that a behavior pattern exists and that standard values exist that can be assigned standard terms.

B. THEORY AND BACKGROUND

The nature of bubble formation was studied extensively and the following observations are the basis for the nomenclature definitions.

Bubble size is primarily a function of two parameters, size of air passage and air velocity; other factors such as temperature, etc., have very little effect.

Each size leak passage has a characteristic minimum bubble size which prevails from the smallest observable flow up to the flow rate at which air velocity becomes the governing factor. When air velocity becomes the governing factor, bubble size gets progressively larger and less uniform, until the air velocity becomes so high that no bubbles can form.

The minimum leak that can be reliably detected is approximately 0.001 scim (standard cubic inches per minute). This is approximately three bubbles per minute on threaded AN flare fittings and the formation of a patch of milky-white foam about the size of a match head on a flanged fitting in 1 minute.

Highly skilled observers can detect lower leak rates under ideal conditions, but the limit of 0.001 scim is used as the lower limit in this report as it can be detected routinely by properly trained personnel under usual field conditions.

Air passage size, as discussed above, is the basic parameter governing bubble size from minimum leak up to the point at which air velocity governs. Most threaded flare fittings have the same order of magnitude thread clearance and, at low flows, all leakage past the flare escapes by this route, unless blocked by excessive thread lubricant.

This commonality of thread clearance passages explains the characteristic small uniform (approximately 1/64 to 5/64 inch diameter) bubbles that occur and persist on threaded flare fittings as shown in figure 1. As the flow rate increases, a definite point is found where air velocity causes larger bubbles of random size to form and persist as shown in figure 2, although for a shorter time. A second distinct change occurs at some higher flow where very large bubbles form that are short lived. This is not shown in a photograph as it is a dynamic condition that in a single frame photo looks like the previous photo.

Flanged fittings exhibit an entirely different behavior at low flow rates. The characteristic leak through a flanged fitting is a number of very fine hair-like leak paths and results in very small bubbles which, through a defraction phenomena, often appear as a milky white within the liquid detection agent and may build up like a deposit of shaving cream lather as shown in figure 3.

At higher rates where air velocity is the governing parameter, larger bubbles of random sizes occur as in the threaded fitting (figure 4).

C. NOMENCLATURE

The observations of bubble appearance as a function of leak geometry and leak rate lead to dividing fitting leaks into two types, threaded and flanged, and each type into three classes. The threaded type includes all connections where the leak passage is surrounded by mating threads. Flanged types include all connections held together by bolts or special clamps where the leak path surfaces are clamped together.

The classes within the types are defined as follows:

Threaded Type:

Class I - Small, uniform (approximately 1/16 inch diameter) long persisting bubbles.

Class II - Mixture of random size bubbles, moderately persistent.

Class III - Large, fast forming bubbles of short persistence, most break as next one starts.

Flanged Type:

Class I - Steady formation of very small, long persisting bubbles, frequently too small to see as individual bubbles, thereby creating a characteristic milky appearance which may build up to a shaving cream lather-like appearance.

Class II - Mixture of random size bubbles of moderate persistence.

Class III - Large, fast forming bubbles of short persistence and most break as next one starts.

An audible leak should be so described although it may be Class III. In the case of multiple class appearances, the larger one shall apply. When more than one point is leaking in a single connector the total estimate shall be adjusted.

Occasionally, a leak in such things as a porous casting will have the appearance of a connector type leak and should be described by the apparent type and class.

D. TEST EQUIPMENT

1. Special fixtures and gaskets

(a) Flared connector manifold

(b) Special flange fixtures - one bolted and one clamped

(1) Teflon gaskets

(2) Soft rubber gaskets

(3) Composition gaskets

(4) O-ring gaskets

2. Microflowmeters

3. Porter volume meters, manufactured by Brooks Instrument Co.

4. Electrical timers

5. Stop watches

6. Sherlock I - liquid detection agent made by Winton Products Company, Charlotte, North Carolina

7. Assorted machined AN flare connectors

8. Filtered dry air (-65°F dew point)

E. TEST PROCEDURE

In investigating the threaded type of leaks, three series of machined Parker-Hannifin Triple loc fittings were intentionally damaged by scoring their sealing surface. Then the pneumatic pressure and connector torque were varied to give the visual indication within the class description. When the desired appearance was obtained, the leak was enclosed in a special chamber and measured with a positive displacement volume meter and a timer. This procedure was followed for three series of five tube sizes each.

Limited quantities of the ratchet type self-locking fittings and dry-lubricated fittings were similarly tested.

In evaluating the flange type leaks, two fixtures were used. One of the fixtures was made from a flat plate and a small chamber held together by an external bolted clamp. The second fixture was two flat plates bolted together and having a machined cavity in one plate for volume. The bolt torque and pneumatic pressure of both fixtures was changed to obtain the desired visual effect. The fixture was then put into a test chamber and the leak volume measured. Precautions were taken to assure no leaks except the one being measured.

F. RESULTS

Fifty-five samples (11 each of 1/4, 3/8, 1/2, 3/4, and 1 inch) of flared tubing connectors were tested to obtain quantitative values for transition flow rates. It was found that the spread on all sizes was very similar for each transition and that a meaningful pattern emerged. These data are presented in figure 5.

This figure presents the data as a distribution plot with percent of population on the vertical axis and flow plotted logarithmically on the horizontal axis. From this plot it can be seen that the transition from class I to class II is contained between 0.1 and 1.05 scim with the bulk between 0.2 and 0.7 scim with the mean at 0.4 scim. Similarly, the class II to class III transitions are contained between 1.0 and 10.0 scim with a mean of 2.8 scim, and the upper limit of class III is contained between 10.0 and 100.0 scim with a mean of 47.0 scim.

Nine flange type fittings (3 each with gaskets of rubber, alpax, and teflon) were tested. These data are shown in figure 6 as a distribution plot, again with percent of population on the vertical axis and flow rate on the horizontal axis.

These results are much less definitive than those for threaded connectors. This is attributed to the probability of multiple leak paths that cannot be separately observed. The second transition (from class II to class III) overlaps the other two to a considerable degree; however, it is still possible to find a useful pattern. The transitions from class I to class II range from 0.1 to 5.0 scim with a mean of 1.3 scim, the transition from class II to class III range from 1.0 to 11.0 scim with a mean of 4.0 scim, and the upper limit of class III ranges from 6.0 to 90.0 scim with a mean of 50.0 scim.

G. CONCLUSIONS AND RECOMMENDATIONS

It is concluded that fitting leaks can be divided into types and classes as described in paragraph C, and the approximate flow rates can be estimated as follows:

	Threaded Type	Flanged Type
Class I	0.001 to 0.4 scim	0.001 to 1.3 scim
Class II	0.4 to 2.8 scim	1.3 to 4.0 scim
Class III	2.8 to 47.0 scim	4.0 to 50.0 scim

With experience, an observer can further refine the estimate within Class I of both types, especially at the low end, by observing buildup per unit time.

For threaded fittings, each class I bubble is usually 1.3×10^{-4} cubic inches. Therefore, a bubble count for 1 minute multiplied by 1.3×10^{-4} will give an approximation in scim.

For flange class I leaks, the volume of accumulated foam after one minute can be estimated for approximate flow rates.

It is recommended that the nomenclature, definitions, and pictures presented in this report be used as a standard to describe leaks.

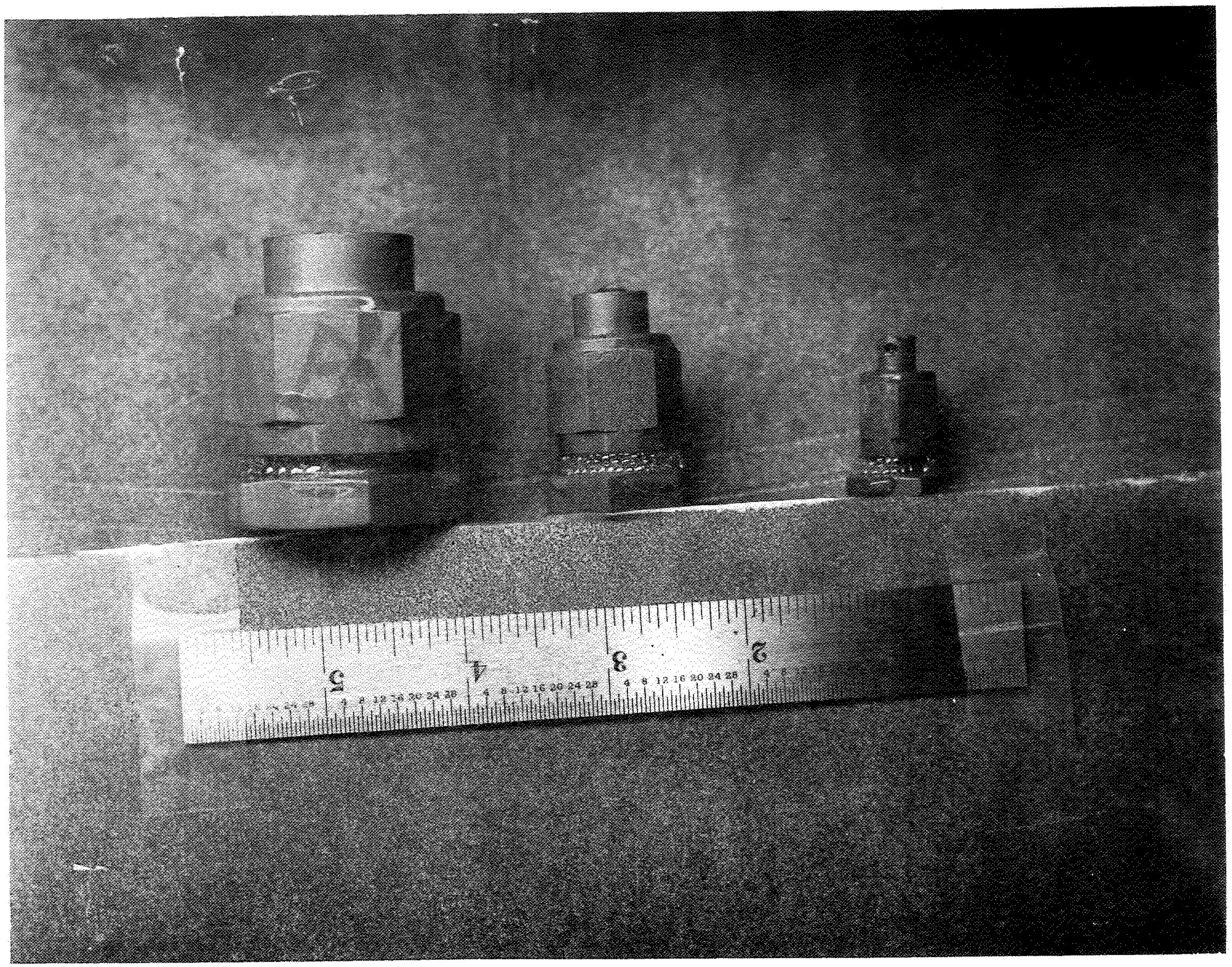

Figure 1. Threaded Leak, Class I

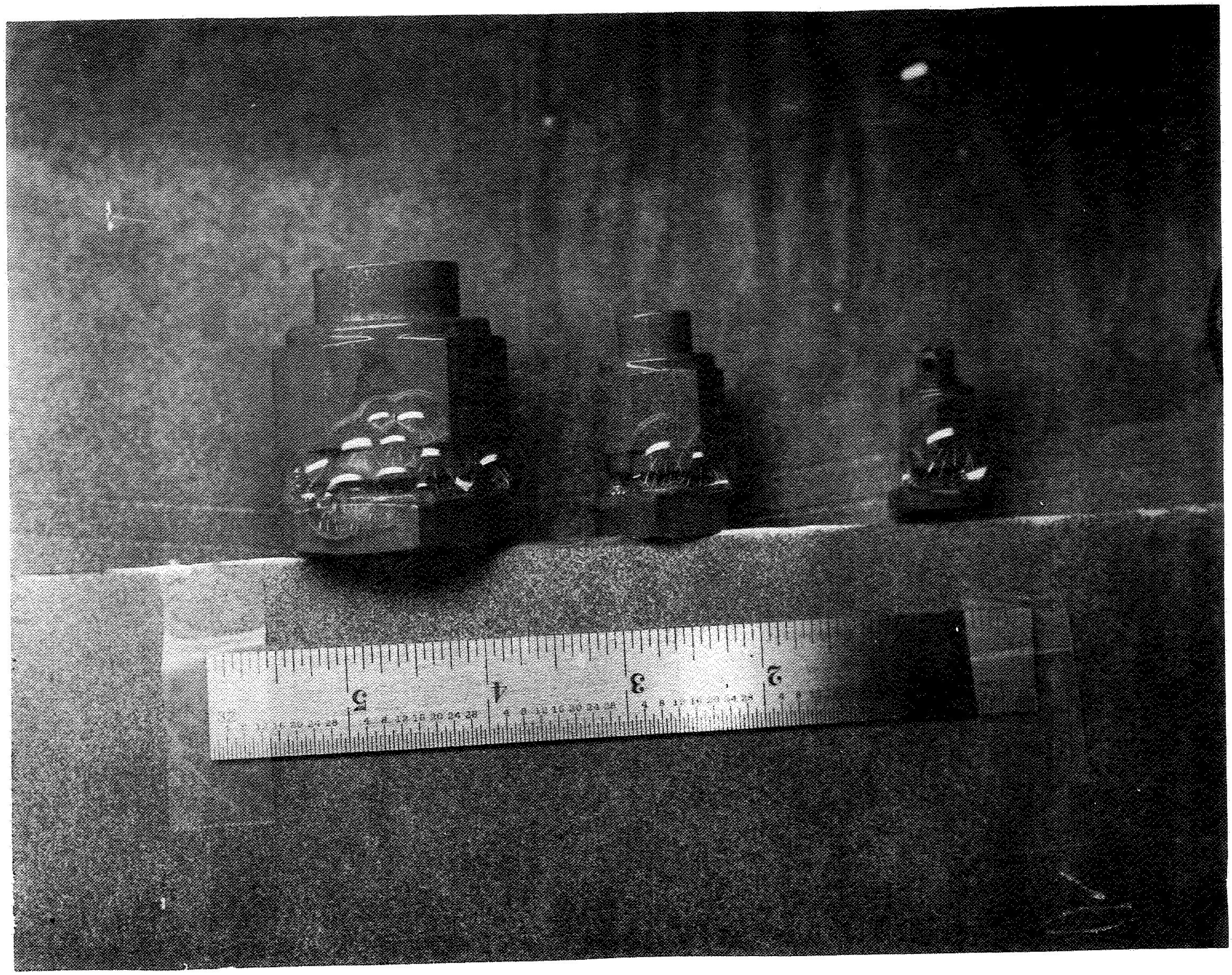

Figure 2. Threaded Leak, Class II

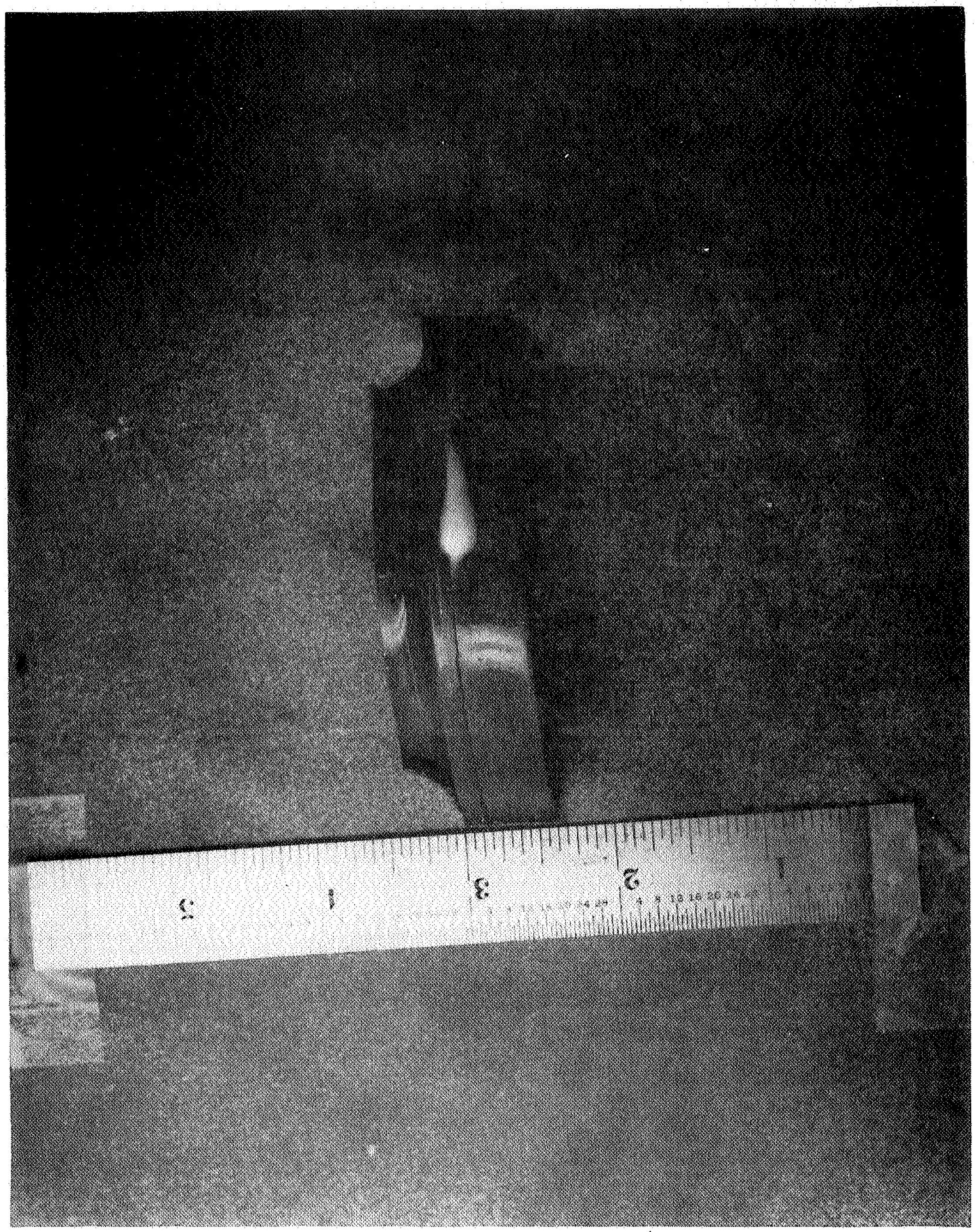

Figure 3. Flange Leak, Class I

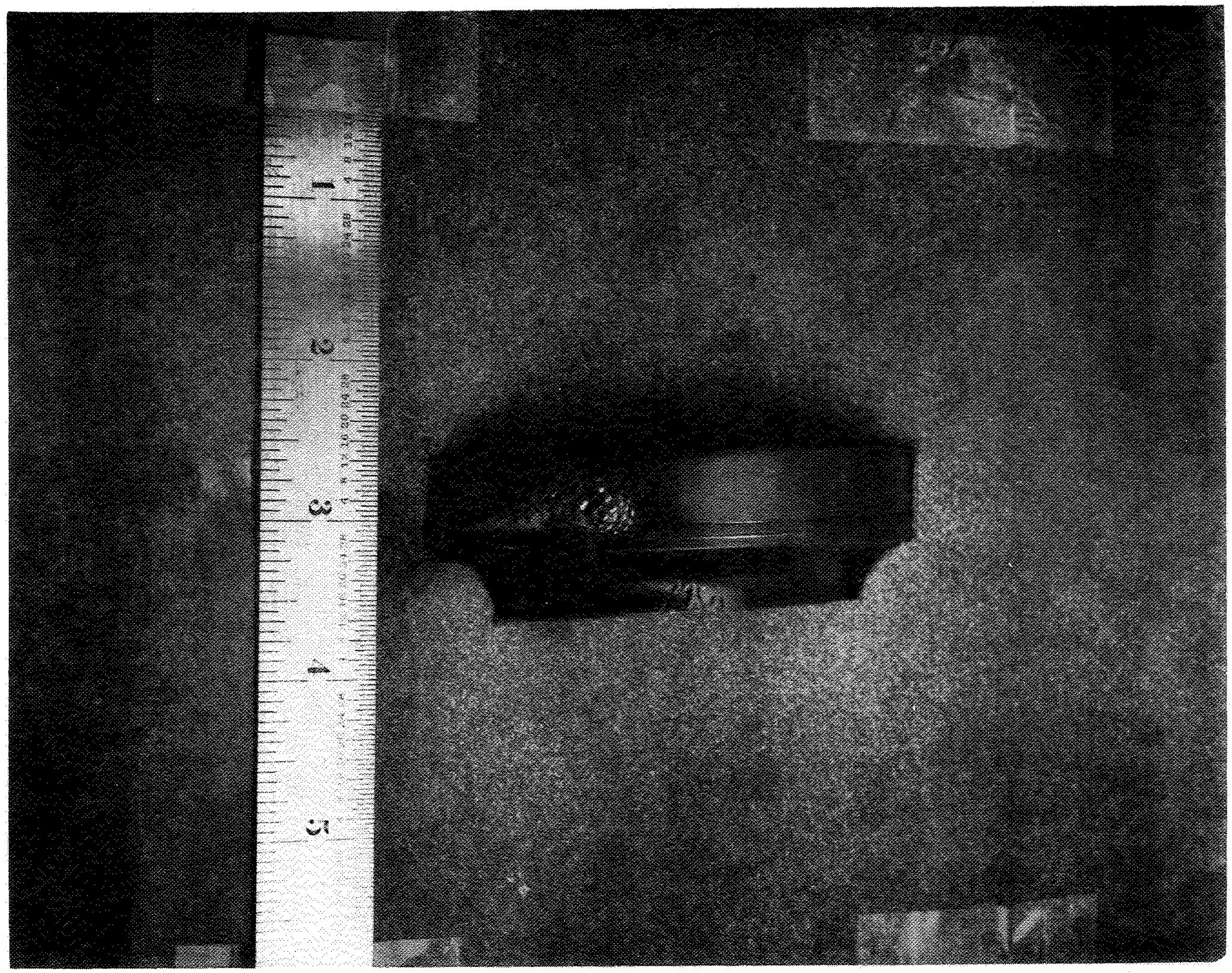

Figure 4. Flange Leak, Class II

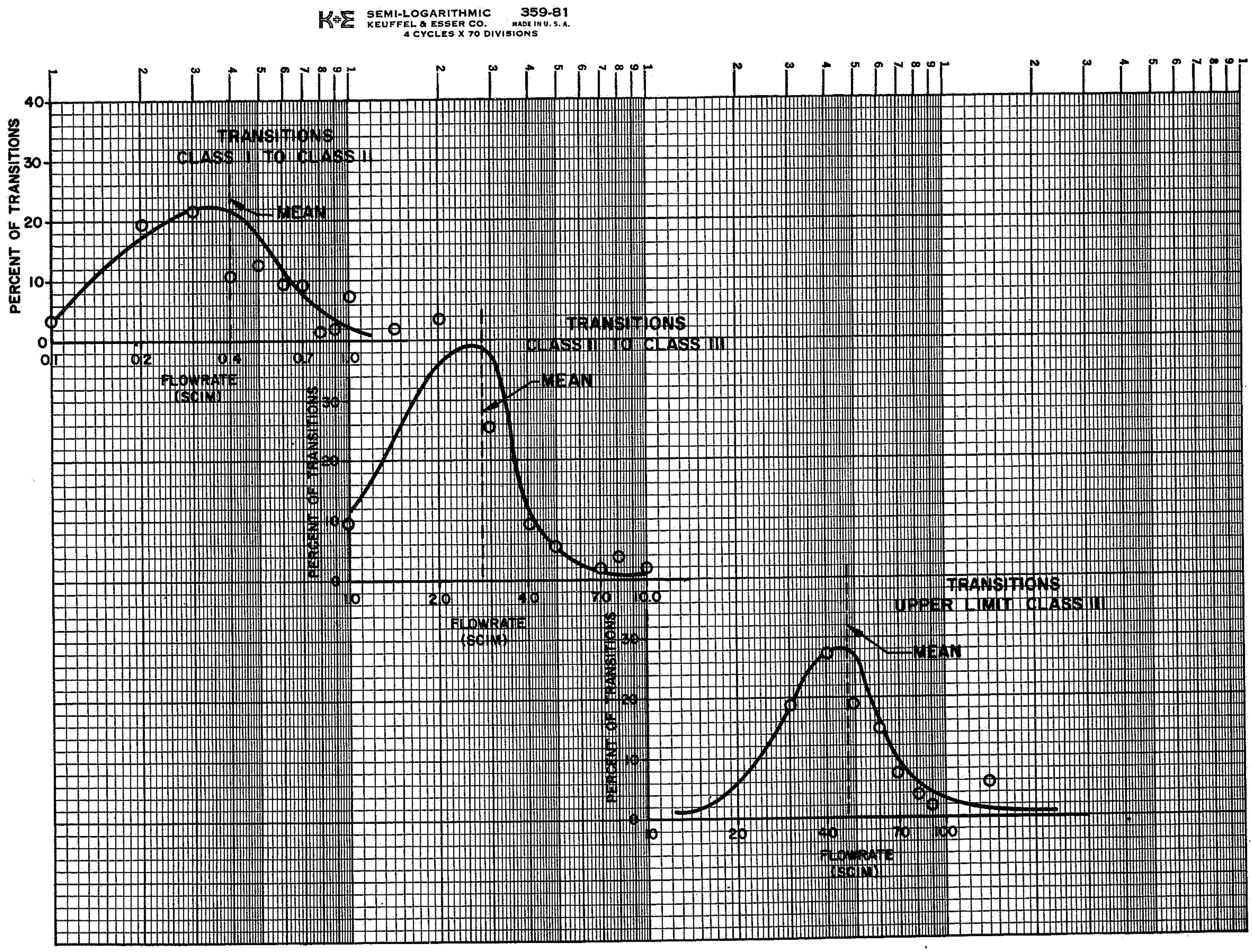

Figure 5. Threaded Fitting Leak Transition Ranges

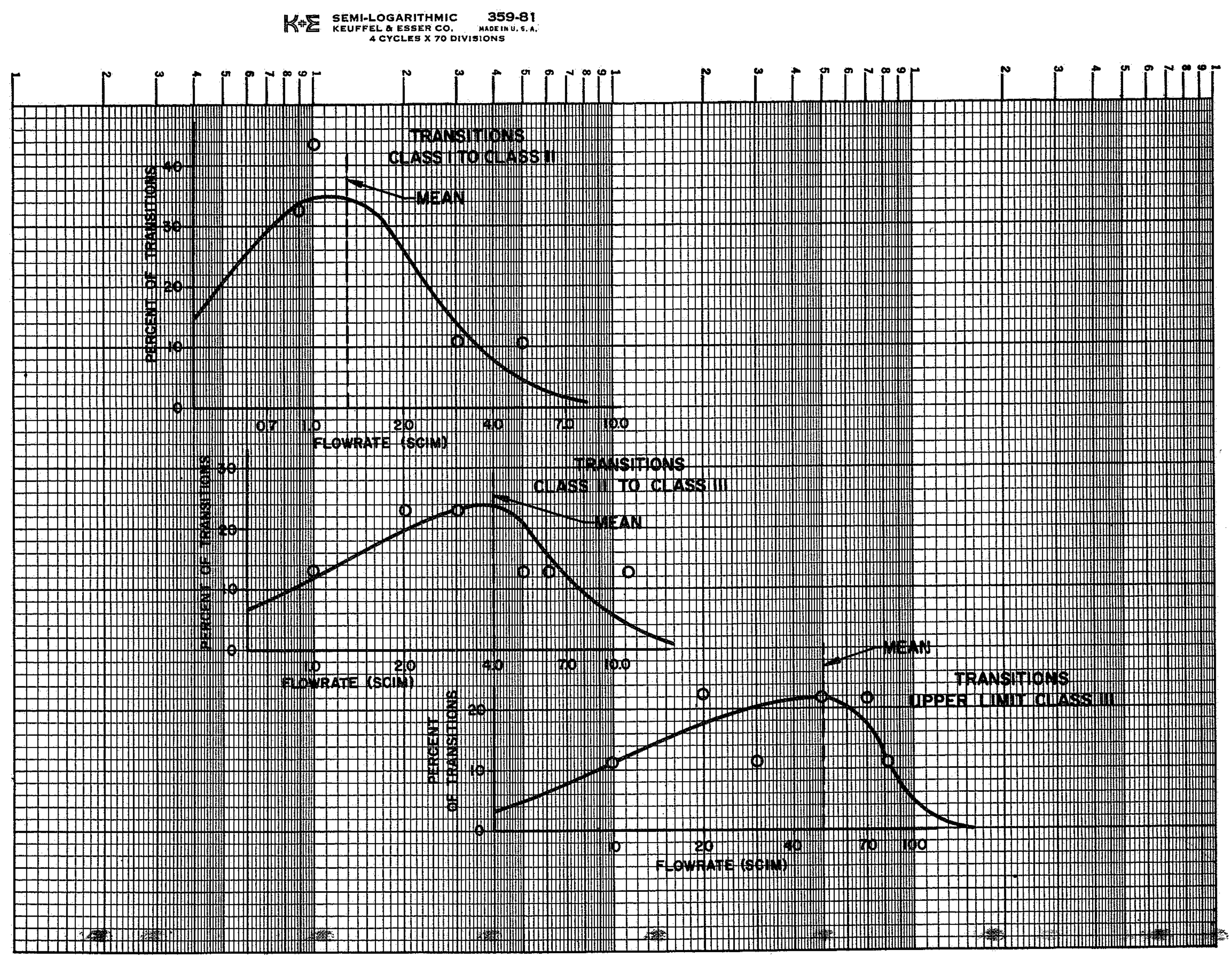

Figure 6. Flanged Fitting Leak Transition Ranges

APPENDIX

PROCEDURE FOR DESCRIBING AND ESTIMATING LEAKS IN AEROSPACE PLUMBING

A. PURPOSE

The purpose of this procedure is to provide a means of describing leaks found with liquid detectors and estimating leak rates in such a way as to improve communications between inspection personnel and persons making disposition decisions, through the use of standard nomenclature with quantitative meaning.

B. NOMENCLATURE

Only the following terms will be used:

1. Type Designation

a. Threaded fittings. All connectors where the leak path is surrounded by mating threads, such as AN flare connectors and pipe threads.

b. Flange fittings. All connections held together by bolts or clamps so that the leak path is between flat surfaces.

2. Class Designations. Within the types, three classes exist. These are determined by observing the kind of bubbles formed and using the following descriptions to select the proper designation:

a. Threaded type.

Class I - Small, uniform (approximately 1/16 inch diameter bubbles) long persisting bubbles (figure 1).

Class II - Mixture of random size bubbles, moderately persistent (figure 2).

Class III - Large, fast forming bubbles of short persistence. Most break as next one starts.

b. Flanged type.

Class I - Steady formation of very small, long persistence bubbles, frequently too small to be seen as individual bubbles, thereby causing a characteristic milky appearance which may build up to a shaving cream lather-like appearance (figure 3).

Class II - A mixture of random size bubbles of moderate persistence (figure 4).

Class III - Large, fast forming bubbles. Most break as next one starts.

3. Other Cases.

a. Audible leaks. These are usually larger than Class III and should be described as audible regardless of whether bubbles form or not.

b. Combinations of classes. Use the name of the larger class if characteristics of two classes are found at same leak.

c. Leaks in castings. Leaks in castings may look like either type, and should be described by the type and class most similar.

d. Multiple leaks. Joints with more than one leak location shall be described as mutiple leaks and each leak separately described.

C. ESTIMATING LEAK RATES

Leak flow rates may be estimated using the following guides; however, these estimates may be in error by a factor of two or three in special cases.

1. Leak Rate Ranges for Threaded Fittings

Class I - between 0.001 scim and 0.4 scim

Class II - between 0.4 scim and 2.8 scim

Class III - between 2.8 scim and 47 scim

2. Leak Rate Ranges for Flanged Fittings

Class I - between 0.001 scim and 1.3 scim

Class II - between 1.3 scim and 4.0 scim

Class III - between 4.0 scim and 50 scim

Further refinements may be made in flow rate estimation by observing buildup per unit time, especially in class I leaks.

Threaded Class I - Count bubbles for one minute. Multiply by 1.3 x 10^{-4}. This will give an approximation in scim.

Flanged Class I - observe buildup for one minute, estimate volume in cubic inches. This will give an approximation in scim.

February 12, 1968 NASA TM X-53692

APPROVAL

PROPOSED STANDARDS DESCRIBING AND ESTIMATING LEAKS IN AEROSPACE HARDWARE

The information in this report has been reviewed for security classification. Review of any information concerning Department of Defense or Atomic Energy Commission programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

This document has also been reviewed and approved for technical accuracy.

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