Second Morning Session

AIR CLEANING SYSTEM COMPONENTS

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FIRST: Now that we have had a review of complete systems, the remainder of the morning program will be concerned with a consideration of the individual system components.

The first discusser will be Mr. A. H. Peters from the Savannah River Laboratory. Mr. Peters has an excellent background on the topic of moisture separators. He has done a great part of the basic work on which we depend for experimental data.

MOISTURE SEPARATORS

by

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The following summarizes the presentation on the function, features, and testing recommendations for moisture separators in reactor containment applications. The information was based on experience at the Savannah River Laboratory and Savannah River Plant as contained in the attached references.

This paper summarizes the functions, features, and some of the test recommendations that we would like to make on moisture separators. I will use the more general term rather than demisters.

Table I summarizes the functions of moisture separators - the primary function is to remove entrained liquid particles from steam air mixtures under reactor conditions to protect high efficiency particulate filters from significant rupture. The secondary function is to reduce atmospheric dust loads on high efficiency particulate filters and thus extend their life.

Table II summarizes some of the features of the moisture separators that are used at the Savannah River plant (1, 2, 3).

First of all, inertial and flow line interception are the controlling mechanisms for liquid particle removal, and I do not intend to spend any time discussing the mechanisms that are well documented in the literature.

The units are mats in our own application woven from teflon yarn and consist of monofilaments about one mil. in diameter, many collected together to form a yarn, and then wrapped on a stainless steel wire which acts as support.

Figure 1 is a face view of the full size unit which is two feet by two feet and the total mat is two inches thick. Figure 2 shows the closeup view of the structure of the mat.

The number of individual mats in the separators (Table II) is dictated by the delta-P requirement which we have correlated in terms of our own test for removal of liquid water particles.

The calculated efficiency for these units is 99-plus per cent for two micron water particles--notice I use the word "calculated." In the final analysis, our tests have proved the effectiveness of the moisture separator, and the actual full-size test demonstrates that the particulate filters do not fail when subjected to simulated reactor conditions.

The rated delta-P of the unit is 0.95 inch water which is what we require the manufacturer to control within plus or minus 0.05 inch water at a face velocity of 8 feet per second. At lower velocities, the efficiency for a given particle size would be less because inertial and flow line interception are the controlling mechanisms.

Table I

MOISTURE SEPARATORS

Primary Function

- Remove entrained liquid water particles from steam-air mixtures under reactor accident conditions to protect high-efficiency particulate filters from significant rupture.

Secondary Function

- Prefilter air to reduce atmospheric dust load on high-efficiency particulate filters.

Table II

FEATURES OF MOISTURE SEPARATORS USED AT SAVANNAH RIVER PLANT[1,2,3]

- Inertial and flow-line interception controlling mechanisms for liquid particle removal.
- Mats woven from "Teflon"* yarn (~1 mil monofilaments) and stainless steel wire (6 mil).
- Number of individual mats in separator dictated by ΔP requirement for 99+% efficiency for 2μ H_2O particles.
- Separator size: 2 ft x 2 ft x 2 in thick.
- Rated ΔP of 0.95-inch H_2O at face velocity of 8 ft/sec.
- Designed and tested to withstand:
  - Wet steam flow 10+ times normal flow
  - Steam-air mixtures for ~10 days.
- Flooding rate 8 times maximum entrainment rate.
- ~30% efficiency for atmospheric dust.
- Long service life; dust removed periodically by steam cleaning.[4]

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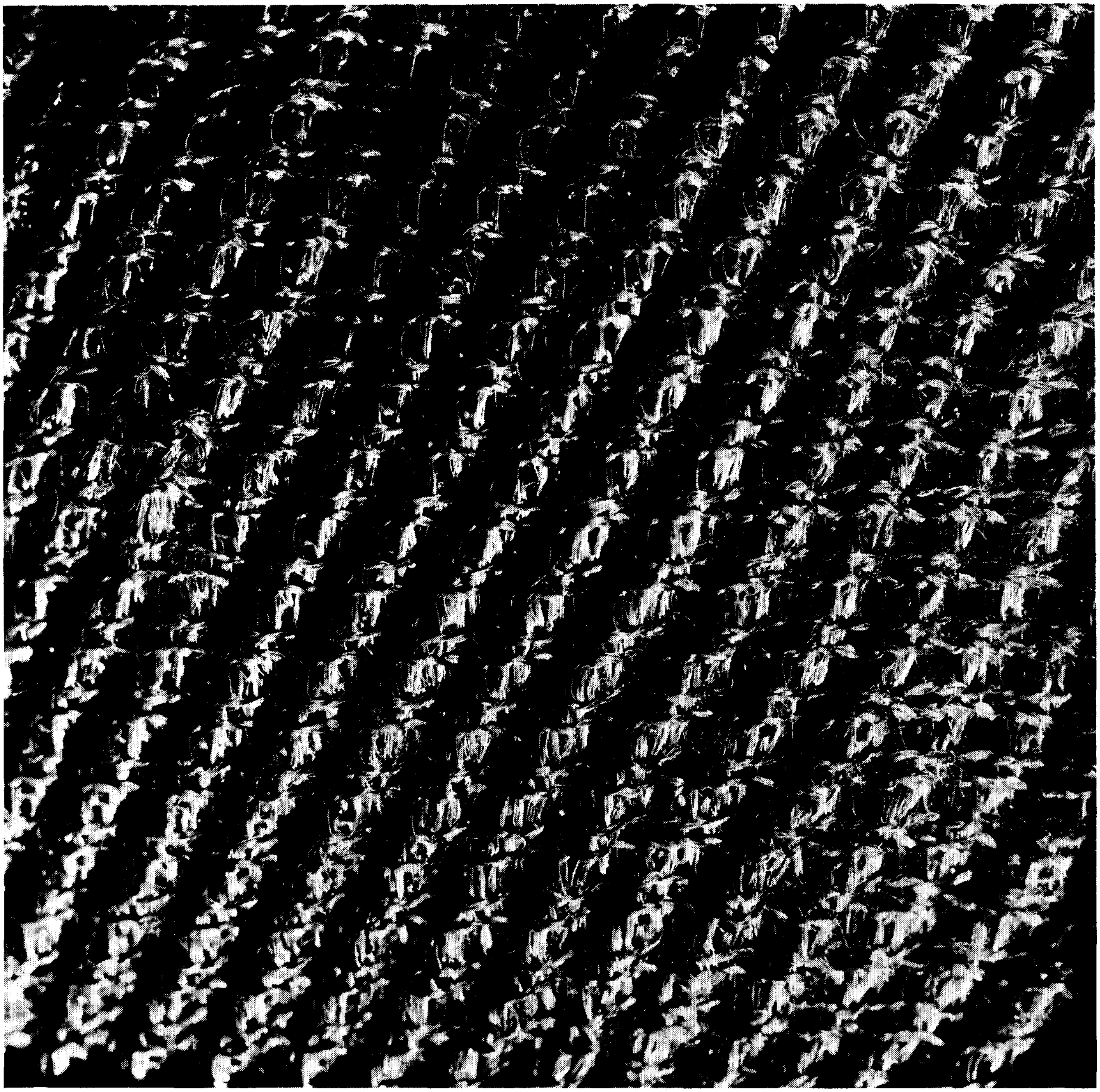
* Registered trademark of E. I. du Pont de Nemours & Co.

Upstream Face of Moisture Separator Used in Reactor Confinement Systems at Savannah River Plant

Figure 1



Moisture Separator Mat Details

Figure 2

Our units, in summary, have been designed and tested to withstand wet steam flow with atmospheric pressure at ten times normal flow followed by exposure to steam-air-entrained water mixtures for periods up to ten days. Numerous tests on both clean and dusty full-size moisture separators and particulate filters have demonstrated the effectiveness of the units under these conditions.

The flooding rate of the demister is about eight pounds of water per minute at the rated face velocity, which in our application is about eight times the maximum entrained rate under accident conditions.

Based on tests in which we used a HEPA filter downstream to collect atmospheric dust, the maximum efficiency for dust in our particular application, which has an average diameter of about three microns, is 30 per cent (Table II). These units are much less efficient for solid particles, because at such high face velocities most of the smaller solid particles bounce off the monofilaments, reentrained in the air, and carried through the moisture separator.

Mr. Hinton of our plant is presenting a paper on Friday in which he will describe in more detail the service of these units. We expect a very long service life, and periodically the moisture separators are exposed to steam to remove the dust cake from the upstream face of the separator.

Our recommendations are summarized in Table III. First of all, we recommend testing under simulated accident conditions of a full size moisture separator, followed downstream by a full size high efficiency particulate filter, particularly if the conditions and the performance requirements under accident conditions for a particular reactor application differ significantly from experience. I will not begin to discuss all the potential applications. There are obviously some that fall outside the range of experience that we've gained at Savannah River (1, 2, 3) and by the British (5), which was reported at the 9th Air Cleaning Conference and by the work of R. D. Rivers and J. L. Trinkle (6), which simulates more generally power reactor accident conditions.

We recommend full size units be tested because of significant scaling problems. The ratio of face area of the particulate filter to that of the moisture separator which is indicated by the difference in face velocity, is about a factor of a hundred. Testing of a small sample from a particulate filter would require a very small diameter separator; in fact the diameter would be significantly less than the depth of the bed and we would be concerned about the effect of the wall (and other factors) on the performance of the units as related to full-size units.

Finally, we recommend only periodic in-place measurements of flow and pressure drop across these moisture separators. No other tests are recommended.

We find in our own application that dust does build up on the front face of the separator, and the actual removal efficiency is increased. One cannot take too much credit for this, because we also find that when the separator is exposed under simulated accident conditions the steam-air-entrained water mixtures rapidly washes the dust off the demister and this, of course, is how we clean the unit.

Table III

SAVANNAH RIVER LABORATORY RECOMMENDATIONS ON MOISTURE SEPARATOR TESTING

- Testing under simulated accident conditions of a full-size moisture separator and a full-size high-efficiency particulate filter is recommended if the conditions and performance requirements for a reactor application differ significantly from experience.[1,5,6]

- Periodic in-place measurements of the flow and pressure drop across installed moisture separators are recommended. No other in-place tests of moisture separators are recommended.

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DISCUSSION

NOBLE: I'm somewhat distressed by the proposal to test full size demisters under accident conditions. I believe your reference number (6) by Trinkle and Rivers covers a test of a reasonable model size not a full size demister. I think this is a much more practical approach than attempting to test the full size demister under accident conditions.

PETERS: Well, I don't think we would quibble with a unit of reasonable size such as dimensions of one foot by one foot, but you do have to scale properly the particulate filter which is downstream and the velocity conditions to that of the demister and in our own particular application, when we test full size units, we run with 1.6 particulate filters downstream of a full size demister, so we block off 40 per cent of the upstream and downstream faces of one of the particulate filters.

NOBLE: My comment was directed of course to filters which are two by two modules and testing of a filter this size, I believe, is quite representative of what a full installation would be.

I believe this was the case with the Trinkle and Rivers report.

PETERS: We have run actually both types of tests and find no difference in the tests where we scale down on a full size filter, or scale down a full-size demister, but we are talking about just a 40 per cent change of four square feet which is still a sizable unit.

I was mainly directing my comment towards small, flat samples of particulate filter medium which for instance might be three inches in diameter. This would require a demister a quarter or half an inch in diameter and two inches thick.

RIVERS: Mr. Peters, I wonder if you have any suggestions as to the simulant for the droplet condition and whether there should be some sort of standard for this.

For us it was quite a difficult problem to create the desired droplet cloud at the face of the moisture separator. There was considerable discussion whether the cloud was an adequate simulation of the cloud which will actually reach the separator location following an accident.

PETERS: Unfortunately, I don't really have any good suggestions for you. We looked into this problem eight years ago. There's a lot more new technology and new particle selections are available today.

We have done DOP tests using the poly distributed DOP system that was described yesterday. The efficiency for DOP with an average particle diameter of about 0.7 micron--and that's a numeric average--is about 20 per cent at the rated face velocity.

The efficiency increases to 60 to 70 per cent after several months exposure to dust, but the real problem really gets around to your particular case for different applications.

The question is -- what is the particle distribution and size in the containment application? The tests we ran were very conservative in that the steam and air were mixed 15 feet upstream of the demister, and the residence time in the system was less than a half a second. In most containment applications, I would expect much longer residence time which allows time for the small particles to coalesce and drop out before reaching the demister.

RIVERS: I was referring to droplets in this case.

PETERS: Well, so am I--liquids and droplets.

FIRST: Mr. Fish, did you want to make a comment or question?

FISH: Yes. I want to ask Mr. Peters when he said a 30 per cent efficiency reflected in the atmospheric dust, was that on a weight basis or mass basis?

PETERS: That was a mass basis.

FISH: A mass basis?

PETERS: Yes.

FIRST: The next topic on your program calls for a review of filters by your chairman. We will have a discussion on this and the remaining papers at the end. Following my presentation will be Dr. W. L. Anderson of the Naval Research Laboratory, who has had a very intimate association with all of the developments at this very important laboratory and his principal discussion will be concerned with a recent government-industry meeting on standardizing filter paper and filter testing.

Dr. Anderson will be followed by Dr. Schwalbe from the Herty Foundation. Dr. Schwalbe is an expert in paper chemistry. His interest in AEC problems is of somewhat more recent origin. Dr. Schwalbe's paper will precede a discussion of gaskets by Mr. L. Sims and F. E. Adley of the Hanford Environmental Health Foundation. These gentlemen have a long history of involvement in filter testing and filter development.

FILTERS: PREFILTERS, HIGH CAPACITY FILTERS, AND HIGH EFFICIENCY FILTERS; REVIEW AND PROJECTION.

by

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High performance aerosol filters, i.e. porous materials having high particle collection efficiency and low airflow resistance, were developed and came into wide use during World War I in response to urgent requirements for personal protection by the use of respirators (or gas masks, as they came to be called) against toxic war gases and screening smokes. Although dust filters and respirators for industrial use were by no means unknown prior to this time, performance and reliability requirements had not been rigorous enough to stimulate a concerted effort toward improvement. Gas warfare changed this very suddenly and a variety of improved filter materials were improvised by the warring nations. The U. S. gas mask canister, for example, consisted of a felted woolen cloth wrapped around a bed of activated charcoal prepared from nut shells. The British used cellulose filter papers that were treated with carbonaceous smoke or magnesium oxide to bring filter efficiency to the desired level (1).

After World War I was over, and gas warfare had been outlawed by the League of Nations, interest in high performance aerosol filtration waned and little was accomplished in the U. S. for about 20 years. This was not the case in Europe. About 1930, Dräger-werke, in Germany, patented a gas mask filter material containing asbestos fibers that were dispersed among

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coarser carrier fibers by brushing and carding after the asbestos had, first, been cleaved to fiber sizes less than 0.25 micron. It was found that greatest efficiency could be achieved with either African or Bolivian blue crocidolite which can be reduced to very fine fibers of exceptional length by mechanical beating. During this same year, Hansen, in Copenhagen, found that when colophony resin was added to a wool filter pad as a fine powder or dissolved in a volatile solvent such as carbon tetrachloride, a great increase in dust retention resulted. This was the best smoke filter in the world for many years and was used by Dutch, French, and Italian armies, as well as by the Danes (2). Hill, a Briton, found in 1938 that mechanical carding of resin-impregnated wool greatly improved dust collection efficiency of the felt cloth made from these fibers. In addition, he discovered that mechanically induced friction restored spent resin-wool fibers, confirming the electrostatic nature of the enhancing dust collection mechanism. This material was used by the British for gas masks during World War II. Although very high collection efficiencies are obtainable against toxic smokes, resin-wool loses its effectiveness when it becomes wetted or when the fibers become oil coated because of a loss of electrostatic charge when the surface film on fibers and resin particles becomes more electroconductive.

The Germans continued their interest in cellulose-asbestos filter materials and developed a mixed fiber paper composed of fine asbestos dispersed in esparto grass fibers that had unusually high particle retention characteristics, acceptable resistance to flow, good dust storage characteristics, and resistance to plugging from oil-type screening smokes.

In the early days of World War II, the British sent to the U. S. Army Chemical Corps Laboratories at Edgewood, Maryland, a piece of this paper that had been removed from a captured German gas mask canister. This was just what the Chemical Corps had been seeking for use as a gas mask smoke filter and they, together with the Naval Research Laboratory, proceeded to duplicate it and have it manufactured in large quantities on conventional paper-making machinery by the Hollingsworth and Vose Company. The first successful paper for the U. S. Navy, containing Bolivian crocidolite, was called H-60. The U. S. Army paper, containing African crocidolite, was designated H-64 and later was called Type 6 by the Army Chemical Corps.

The NDRC, acting for the armed services, solicited the assistance of a number of university and industrial scientists in the search for better smoke filters and this resulted in important U. S. advances in the theory and technology of aerosol filtration. Up to this time, aerosol filtration theory had been derived almost exclusively as an off-shoot of water filtration knowledge but now, because of the needs of the military, people like Nobel Laureate Irving Langmuir examined the physical bases for particle retention on fibers or small granules. He concluded (3) that the principal mechanisms involved were interception, which affected suspended particles substantially greater than 0.1 micron diameter when moving through a devious flow path in a bed of porous material, and diffusion, which affected suspended particles substantially less than 0.1 micron. His analysis, later modified by Ramskill and Anderson (4) to include inertia, indicated that the combined effects of these forces on a particle would be at a minimum when the particle was 0.3 micron diameter and he advised NDRC to test their gas mask filters with smoke of this size to determine minimum retention efficiency. He indicated that if particles were present during field use of the gas mask that were either greater or smaller than 0.3 micron diameter, they would be removed at higher efficiency than the 0.3 micron test particles.

After the war, Victor LaMer, of Columbia University, performed many experiments to examine Langmuir's theory of a minimum filterable particle size and concluded that efficiency declined as particle size decreased below 0.3 micron. Others produced results that confirmed a minimum filterable particle size, but not necessarily at 0.3 micron. This is understandable, as subsequent study has shown that other forces not taken into account by Langmuir, such as particle inertia, flow rate, and naturally occurring electrostatic charges on particles and filter medium, may also affect collection efficiency. Whatever may be the historical judgment on the correctness of Langmuir's theory, it affected U. S. filter technology profoundly and led directly to the development of the DOP filter test by LaMer and Sinclair for NDRC during 1942-1945 which has become a standard method for rating ultra-high efficiency, or absolute, filters (5). Prior to this, the Chemical Corps had been using a test aerosol generated from methylene blue dye dispersed from water solution and dried that had been developed in 1940 by Walton in Britain. Walton developed the sodium flame test in 1941 to greatly speed up the testing of gas mask canisters as the methylene blue test procedure is a relatively slow method. The sodium flame test is still widely used in Britain.

Protection against chemical warfare agents is also required for operational headquarters, where the wearing of an individual gas mask is impractical. For these situations, the Army Chemical Corps developed a mechanical blower and air purifier known as a "collective protector" unit. As relatively large air volume flow rates were required, the smoke filter, incorporating a cellulose-asbestos paper known as CWS type 6, was fabricated into the deeply-pleated form with which we are now quite familiar. In retrospect, this was most fortuitous as the activities associated with the Manhattan Project developed potential air pollution problems which could be solved only by the use of air filters having characteristics similar to those possessed by the CWS filter and the U. S. Army Chemical Corps became the sole supplier of high performance filters to the Manhattan Project and, later, to the USAEC.

The Chemical Corps and the AEC were disturbed by the fact that both components of the filter medium in the CWS filter (Bolivian or African crocidolite [blue asbestos] and African esparto grass) were imported and difficult to obtain during a period of war when shipping was under attack. Domestic fibers, including yucca, Kraft, and viscose, were used successfully by the Naval Research Laboratory and Hollingsworth and Vose Company as a replacement for esparto and the A. D. Little Company was given a contract to develop a paper of equal or better filtration performance characteristics that could be manufactured entirely from fibers obtainable on the North American continent and would avoid security restrictions imposed by the armed services. Their investigations led them in the direction of coarse glass fibers as a substitute for esparto, Canadian asbestos as a substitute for Bolivian blue, and corrugated separators as a substitute for the block-type separators used by the CWS that proved to be a significant obstruction to air flow (6). The search for domestic sources of filter materials came to a highly successful conclusion in 1951 with the development by the Naval Research Laboratory (7) of all-glass-fiber papers made, in part, from super-fine, spun-glass fibers having diameters substantially below 1 micron. With domestic industry able to produce unlimited quantities of glass fibers as small as 1/4 micron, asbestos was no longer needed. Abandonment of asbestos, which is difficult to disperse, allowed much greater control of manufacturing procedures and the production of better and more uniform papers. The use of asbestos fibers in glass-fiber-containing absolute filter papers increases resistance to HF and results in a slight cost reduction, but better papers can be made without asbestos.

In addition to developing papers from domestic materials, A. D. Little (6), was asked to design a modified absolute filter that would be non-combustible. They developed a prototype filter containing glass-fiber filter paper prepared by NRL, corrugated asbestos paper separators, steel frame, and a furnace cement sealant. The filter was completely resistant to fire, but it was heavy and the refractory furnace cement adhesive embrittled the filter paper, had a distressing tendency to separate from the steel frame, and produced air leaks. This filter became obsolete with the introduction of high-chlorine-content, self-extinguishing adhesives and the development by A. D. Little Company of a fiber blanket seal between filter pack and metal frame, first produced by Cambridge Corporation as a substitute for organic adhesives. Hurlbut Paper Company and Hollingsworth and Vose Company produced an air filter paper in the mid 1950's made from Carborundum Corporation's Fiberfrax fibers (SiO_2 - Al_2O_3) that would withstand temperatures up to 2000°F for long periods and in excess of 3000°F for short periods. With this paper, plus loose Fiberfrax fibers of various grades, Flanders Filters was able to fabricate an all-ceramic filter (i.e., paper, separators, filter-frame, and sealant of Fiberfrax) capable of performing satisfactorily at temperatures in excess of 2000°F and with an extraordinary resistance to heat shock (8). In more recent years, the principal effort has been directed toward improving fire and water resistance of filters of standard construction and toward up-grading quality control. H. Gilbert has described in detail (9) operation of the AEC's two filter test stations and indicated some of the efforts now underway to develop criteria and standard tests for fire resistance and moisture resistance.

As a result of the combined efforts of the AEC, the NRL, and the Army Chemical Center over a period of about 25 years, an extraordinarily effective air filter unit has been developed and produced commercially by 5 or more U. S. companies. I can't resist quoting an anonomous comment by someone attending the 8th Air Cleaning Conference: "We have been sitting here for three days and we have heard some interesting things about filters. We have heard, for example, how many hundred pounds of steam have been passed through a filter at seven times the design rate of flow. They have been heated to 700°F. We attack them with DOP, and others attack them by hitting them with hammers that weigh about 300 pounds. All of this testing is to evaluate filters; actually we have to admit that we have got a pretty good product that we are hitting, pounding, steaming and burning!(10)" And he might well have added, in recognition of the NRL's more recent activities, shooting them through cannons! (11)

Although I have dwelt at length on the development and refinement of the absolute filter, I would be presenting a distorted picture of filter-development in the AEC if I did not refer to other significant, though somewhat less important, air filter innovations. I need not go into a great deal of detail about these as most of you were present at the IAEA Symposium yesterday and heard excellent reports about the performance of sand filters and deep bed fiber glass filters at Savannah River and at Hanford (12). When a high activity-level was detected at Hanford in 1948 and traced to radioactive particles emitted from the chemical processing ventilation stacks, C. E. Lapple, then a chemical engineer with DuPont, recalled the practice of using deep beds of graded granular coke to stop sulfuric acid mists escaping from contact sulfuric acid plants and constructed air filters of graded layers of sand and rock to a depth of about 10 feet (13). These filters operated at a superficial face velocity of 6 ft/min., an initial pressure drop of 8 in. w.g., and an activity reduction of 99.7%. Other units were built at SRL at a later time and each has given many years of continuous service and may continue to do so for many more. It should be noted that air flow resistance is much higher, and retention efficiency lower, than may be obtained with the use of absolute filters, but freedom from servicing and replacement over many, many years is an important advantage when the collected material is intensely radioactive. Nevertheless, there appears to be little current interest in building new sand filters as it is difficult to dispose of them when, finally, they are no longer functional. In addition, sand filters of this type are costly to construct.

When additional air filtration capacity was needed at Hanford in the early 1950's, A. G. Blazewitz (14), then with G. E., instituted a development program to utilize deep beds of graded glass fibers, 5' 4" thick, as a long-lived, more highly efficient, and lower resistance substitute for the sand filters. This filter was in use at Hanford for more than a decade until it became plugged with NH_4Cl. An almost identical replacement is working well on Purex process effluent. It is necessary to point out that although deep bed glass fiber filters proved satisfactory on Purex process effluent at Hanford, there was virtually no interest in using this type of filter elsewhere until we, at HACL, picked up the idea once again a few years ago as a device to collect and store at modest pressure rise very high loadings of sodium fume accidentally released from a fast breeder reactor. This work was reported at the 9th USAEC Air Cleaning Conference (15).

Prefilters have been used at many sites to extend the service life of absolute filters and, thereby, to save on filtration costs. The economy to be obtained from the use of prefilters was reported at the 8th Air Cleaning Conference (16). One of the first installations to use prefilters to extend the life of absolute filters was the original air cooled pile at Oak Ridge. It was found that the service life of the absolute filters could be extended to more than 3 years by changing the prefilters 2 - 3 times per year. Although there have been situations where a cost analysis fails to show an advantage for the use of prefilters, most installations seem to benefit by the use of cheaper prefilters and there is new interest in the use of metal prefilters as they may, in addition, provide fire and blast protection by acting as baffles and fire screens (17).

In spite of the many great improvements in (a) absolute filter efficiency and (b) resistance to fire, blast, and moisture, the full capabilities of improved filter performance are not always achieved because of faulty installation. As a consequence, in-place testing of all filters has become routine at most AEC installations. These tests occur before initial start-up of new facilities and periodically thereafter. Considerable difficulties were experienced in conducting tests at old installations because access to the filter structures had not been provided, but suitable facilities for in-place filter testing are now routinely designed into new clean-up systems as a part of the construction specifications. A great deal has been learned about proper filter installation by in-place testing and a handbook that summarizes installation techniques and the design of suitable structures is under preparation by Burchsted and Fuller (18).

It seems reasonable to conclude that the current level of development of absolute filtration (both filter cartridges and installation techniques) makes it possible, when properly applied, to provide a degree of air cleaning compatible with all current safety requirements. Improvements in fire, shock, and moisture resistance have been substantial during the past several years. They suggest that future developments will occur in an orderly manner and provide even greater freedom from catastrophic failures during periods of severe stress. It is especially gratifying to note the rapid spread of atomic energy-based technology in ultra-high efficiency air filtration to other, quite different, applications such as clean room design and hospital operating rooms.

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GOVERNMENT-INDUSTRY MEETING ON FILTER MEDIA AND MEDIA TESTING

by

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Over the past twenty years we have accumulated a vast amount of knowledge about filter materials. In fact, I would go so far as to say that knowing the physical parameters of the filter (fiber diameter, filter thickness, fiber density, etc.) and the characteristics of the aerosol (particle size and density, flow rate, etc.), we can predict fairly accurately what the expected filter performance will be under operational conditions.

Experimental data is available to show the effect of velocity and particle size on the penetration of well over a 100 different filter materials. The respective velocities and particle sizes for maximum penetration have been established for a number of filter materials under various operating conditions. We understand the differences, if any, between liquid and solid, radioactive and non-radioactive, hygroscopic and non-hygroscopic, homogenious and polydispersed aerosols. We have measured penetrations of filters with particles of all sizes; from pollens down through bacteria, rickettsia, oil smokes, crystalline materials, to the phages and the viruses. These materials cover the size range from 20 down to about 0.01 microns. We are now attempting to extend the range of particle sizes down to the atomic and/or molecular ranges. From this type of data the specifications for the present military and/or HEPA filter materials were developed.

In order to evaluate the available filter media and to establish some method of standardization for specification testing, it is necessary to establish some criteria for uniformity of testing. Early acceptance of the DOP test for this method of test standardization provided a uniform procedure that was easy to administer, at least in the early stages. When first adopted,about fifteen years ago, there was one filter media manufacturer and two filter unit manifacturers. Thus our standardization between individual laboratories and industry was very convenient. There were numerous cross checks and unaminous agreement was easily achieved. Today, however, the picture is altogether different. As of this date, there are six known domestic media manufacturers and seven foreign media suppliers. On the filter unit side, there are five known domestic manufacturers and four foreign suppliers. This gives us a total of 22 separate industrial concerns which now must be coordinated. Thus you can see that the entire field has expanded tremendously in the last fifteen years. If you add to this industrial total the various academic institutions, research and development laboratories and health and safety groups,then we have over 100 filter penetrometers and resistance measuring devices to be coordinated. If to these devices we add the in-place testing groups, the air pollution departments, the specification and testing groups, then over 500 photometers and associated equipment must be calibrated and correlated so that meaningful results can be obtained.

As the number of filter evaluation centers increased, it became apparent that rigid control of the testing procedures was necessary to assure correlation. Early in the program, marked differences were observed between various test sites in both penetration and resistance measurements of test media. In each case the error was in such a manner that it was indicative of errors in flow measurement and/or adjustment. To correct this deficiency, the AEC has established a program with the National Bureau of Standards whereby calibrated reference plates are supplied to the filter testing stations for proper adjustment of their test flows. The application of these plates is sufficiently new that complete data on their use is not yet available. Preliminary results, however, indicate that their use will greatly assist interstation correlation. At the same time we are establishing among all media and unit manufacturers and the testing laboratories standardized procedures for testing of the tensile strength, filter caliper, penetration, and resistance at two separate flows, basis weight, percent moisture and percent combustibles. Once these procedures have been established then it is reasoned that all filter evaluations will be on an equivalent basis.

Many of the accomplishments of AEC air filtration problems achieved thus far have been due to the efforts of an informed working group in high efficiency filters. This group held their most recent meeting this past Sunday for a series of discussions of current interest. This session, following the precedent of earlier meetings, related the operating requirements placed on the high efficiency filter and the capacity of industry to meet them. On the current working group are members of all facets of filter media and filtration unit fabrication. Included are basic fiber suppliers, media manufacturers, unit fabricators, various interested research and development groups,and industrial users of the completed items. It is believed that this group provides an invaluable service by meeting on a frequent basis and presenting their corporate problems so that better filter materials and filtration units can be produced.

At the recent meeting, four separate subjects were discussed and will be mentioned briefly:

(1) <u>Filter Material Survey</u>: AEC requested that all commercial suppliers forward samples of their production filter media to the Naval Research Laboratory for study. The purpose of this study was considered to be twofold. One, to determine whether the various media did conform in all respects to the MIL-F-51079 specification for filter media,and two, to determine whether basis-weight requirements were a necessary addition to the existing filter material specification. Accordingly, physical and performance data were determined on all samples and an attempt was made to correlate performance, media caliper, and basis weight.

Thirty-five different samples of filter media were submitted. These samples were forwarded by six different filter media manufacturers and five different filter unit manufacturers. Since some filter media manufacturers supply their materials to specific filter unit fabricators, some duplication of samples occurred. No filter sample was identified by trade name or manufacturer's number: for propriatory reasons, all samples were assigned consecutive letter designations. The original AEC letter requested that all samples submitted be composed of glass fibers with less than 5 percent combustibles and be representative of production lots of filter materials. Of the total of 35 samples submitted, 8 failed to meet these requirements. Accordingly, these 8 filter materials were not included in the performance-basis weight comparison; their respective physical and performance characteristics are reported separately.

The physical and performance characteristics of the 27 materials included in the basis weight comparison are given in Table 1. Letter designations, with explanatory footnotes, are shown next to those numerical values that do not meet either the percent or proposed acceptance specifications. It can be seen from the data that only 8 of the 27 samples meet all of the existing and/or proposed requirements. The remaining 19 samples failed in one or more of the specified categories.

Since part of the original objective of this study was to determine whether basis weight could be correlated with either physical characteristics and/or filtration performance, a comprehensive comparison of all the experimental data was attempted. Correlation studies were made between basis weight and each of the individual data categories; no indication of interdependence nor even a trend toward dependence of any of the data was observed. It has been previously demonstrated that the filtration performance and the filter physical characteristics are a direct result of the specific fiber diameter formulations utilized by the various filter suppliers. Different filter makers using fibers from the same source and using essentially the same formulation will produce different quality media. It is, therefore, concluded that a basis weight requirement is <u>not</u> an essential part of the filter media procurement specification.

It should be pointed out that all of the filtration efficiencies measured in this study are considerably lower than those achievable from materials produced in the laboratory or procured under military specifications. For comparison purposes, efficiencies as high as 5.5 have been achieved in laboratory pilot runs and the minimum acceptable efficiency for the present Navy filter material is 4.4. These values should be compared with the maximum value of 4.0 determined during this study.

The physical and performance characteristics of the 8 materials not included in the survey are given in Table 2. No letter designations are given for these values which fail to meet the present or proposed acceptance specification. These data are included for information only; no correlations or statistical comparisons were attempted.

Table 1

Filter Materials Included in Survey

Paper Desig.	5.2 cm/sec DOP (%)	5.2 cm/sec Res (mmH_2O)	14.2 cm/sec DOP (%)	14.2 cm/sec Res (mmH_2O)	14.2 cm/sec Eff	Tensile Cross (#/in)	Tensile Mach (#/in)	Water Proof	Combust. (%)	Moisture (%)	Caliper (in)	Basis Wt. (#/3000 ft^2)	Corrected Basis Wt. (#/3000 ft^2/.015")
A	0.030	34	0.082	90	3.4	2.3 D	3.1	Yes	5.6 F	1.0	0.014 E	37.9	40.6
B	0.029	36	0.078	95	3.3	3.4	4.1	Yes	4.8	0.4	0.016	55.4	52.0
C	0.024	38	0.064	100	3.2	3.7	5.1	Yes	5.8 F	0.1	0.016	55.2	51.8
D	0.023	33	0.061	88	3.7	2.8	3.6	Yes	2.3	0.3	0.036	127.1	53.0
E	0.021	36	0.056	95	3.4	2.1 D	5.7	Yes	4.4	0.2	0.013 E	43.9	50.6
F	0.012	36	0.033	96	3.6	2.4 D	5.5	Yes	3.6	0.6	0.014 E	55.3	59.2
G	0.004	44 B	0.010	120	3.3	3.0	4.7	Yes	4.2	0.8	0.012 E	43.9	54.9
H	0.017	34	0.044	90	3.7	3.9	6.0	Yes	1.9	0.2	0.019	52.2	41.4
I	0.019	37	0.050	98	3.4	2.1 D	4.0	Yes	4.1	0.4	0.017	58.5	51.6
J	0.045 A	34	0.120	90	3.2	2.1 D	2.7	Yes	3.6	1.7	0.015	38.7	38.7
K	0.027	34	0.072	90	3.5	3.5	4.6	Yes	5.9 F	1.0	0.018	59.8	49.9
L	0.021	34	0.055	90	3.6	3.6	4.8	Yes	4.5	0.5	0.019	57.2	45.2
M	0.010	34	0.024	90	4.0	4.3	8.0	Yes	2.6	0.1	0.023	63.4	41.3
N	0.021	33	0.054	89	3.7	2.3 D	5.1	Yes	3.6	0.5	0.015	59.7	59.7
O	0.015	38	0.040	100	3.4	1.8 C	5.4	Yes	4.2	0.4	0.011 E	43.9	59.8
P	0.036 A	32	0.098	85	3.5	1.7 C	6.0	Yes	3.1	0.3	0.014 E	53.2	57.0
Q	0.014	37	0.038	98	3.5	3.0	6.1	Yes	2.9	0.2	0.014 E	49.6	53.1
R	0.011	40	0.028	106	3.4	2.3 D	2.9	Yes	5.2 F	0.7	0.016	50.6	47.5
S	0.055 A	33	0.150	88	3.2	2.2 D	3.3	Yes	3.3	1.4	0.016	43.3	40.6
T	0.028	38	0.074	100	3.1	2.4 D	7.0	Yes	4.3	0.4	0.015	54.9	54.9
U	0.015	32	0.040	85	4.0	2.5	4.1	Yes	4.8	1.2	0.017	59.4	52.4
V	0.017	36	0.044	95	3.5	3.0	5.4	No	5.5 F	0.4	0.020	63.4	47.6
W	0.021	37	0.052	98	3.3	4.8	10.0	Yes	4.9	0.2	0.016	58.6	55.0
X	0.011	33	0.029	89	4.0	1.8 C	2.8	Yes	4.9	0.3	0.015	57.5	57.5
Y	0.021	31	0.054	83	3.9	3.4	5.3	Yes	0.7	0.5	0.018	48.8	40.7
Z	0.024	39	0.064	103	3.1	2.4 D	2.9	Yes	3.3	0.4	0.016	50.8	47.7
AA	0.010	41 B	0.027	108	3.3	2.3 D	3.0	Yes	5.0	0.4	0.017	58.0	51.2

A - Maximum penetration - 0.030% - MIL F-51079
B - Maximum resistance - 40 mmH_2O - MIL F-51079
C - Minimum tensile (Cross) - 2.0 #/in - MIL F-51079
D - Minimum tens (either direct) - 2.5 #/in - proposed revision of MIL F-51079
E - Minimum caliper - 0.015" - AEC Health & Safety Memo 212
F - Maximum combust - 5% - AEC Health & Safety Memo 212

Table 2

Filter Materials Eliminated* from Survey

Paper Desig.	5.2 cm/sec DOP (%)	5.2 cm/sec Res (mmH_2O)	14.2 cm/sec DOP (%)	14.2 cm/sec Res (mmH_2O)	14.2 cm/sec Eff	Tensile Cross (#/in)	Tensile Mach (#/in)	Water Proof	Combust. (%)	Moisture (%)	Caliper (in)	Basis Wt. (#/3000 ft^2)	Corrected Basis Wt. (#/3000 ft^2/.015")
BB	0.030	34	0.080	90	3.5	5.0	6.5	Yes	6.7	0.6	.019	60.9	48.1
CC	0.020	39	0.052	102	3.3	3.5	5.0	Yes	6.6	0.1	.018	63.8	53.2
DD	3.000	12	7.000	32	3.6	2.2	3.1	No	6.2	0.5	.018	59.5	49.6
EE	0.051	36	0.140	98	3.0	1.2	1.8	Yes	78.0	2.0	.035	124.3	53.3
FF	2.500	13	6.000	35	3.5	0.9	1.6	No	96.1	1.4	.032	114.6	53.8
GG	0.0007	52	0.002	138	3.4	1.6	4.3	Yes	4.2	0.4	.014	52.6	56.4
HH	0.016	32	0.042	85	4.0	1.1	1.6	Yes	63.5	1.9	.011	47.1	64.2
II	0.0004	51	0.001	135	3.7	0.5	0.7	No	7.2	0.3	.015	40.8	40.8

* Eliminated from survey because of: handsheet, excessive % combustion, or unacceptable res.

(2) <u>Moisture-Resistance Test</u>: The second item of discussion at the meeting related to work of the Herty Foundation of Savannah, Georgia, on moisture resistance tests. Their current work is in connection with the adaptation and/or improvement of the moisture test originally developed by the Savannah River Laboratory. Complete details of the current status of these tests are presented in a paper by Schwalbe of the Herty Foundation; this paper is included elsewhere in the proceedings of the meeting.

(3) <u>Chemical Resistance Fibers</u>: A third subject of discussion concerned the availability of a new glass fiber which was reported to have special acid and/or chemical resistivity over the fibers presently utilized for filter materials. Essentially all of the filter media manufacturers are presently using Johns-Manville 475 glass fibers in their formulations. This material is acceptable for essentially all applications except in a few instances where acid components are a part of the off-gas air that requires filtering. In order to provide additional chemical resistivity, Johns-manville has developed a 731 glass formulation. Pilot quantities of this material were procured and filter media handsheets prepared by Hollingsworth and Vose Company.

The basic investigations on chemical resistivity were conducted by Weber at ORGDP. His tentative conclusions are that filter materials made from the 731 formulation do resist acid materials to a much greater extent than the present 475 materials. At the same time, Knudsen of Hollingsworth and Vose Company conducted comparative tensile strength studies on the two materials. His conclusions were that filter media prepared from the 731 fibers gave measurably lower original tensile strengths than those made from the current 475 fibers.

From these two studies, it appears that by using the 731 fibers two different effects are occurring. A beneficial effect of increased chemical resistivity but at a detrimental effect of lower original tensile strength. The working group recommended that a separate laboratory attempt to confirm the results obtained thus far; the Naval Research Laboratory will perform this task. If the original results are confirmed then a trade-off analysis will be made to determine the relative merits of the new fiber.

(4) <u>Shipping Rates for HEPA Units</u>: The fourth and last subject discussed was the transportation rates scheduling that is presently in effect for shipping HEPA filter units. Information on the propriety of rates assigned by the National Motor Freight Classification A-9 was assembled by Elinsky of Mine Safety Appliance Company, Pittsburgh, Pa. For some time, unit fabrications have felt that they have been penalized by paying extra freight rates on a so-called fragile item. Since the institution of new packaging techniques and the strengthening of the unit design, some consideration might be given to lowering the classification and hence lowering the shipping charges of the units. As a result of the study, it was concluded that there was little hope of lowering the existing rate schedules. However, the study also determined that the probability

of higher rates in the near future is very great, and that the group would direct their efforts toward further increases in shipping rates. The Mine Safety representative offered their transportation management facilities in order to keep abreast of developments so that the filter industry as a whole can benefit.

In conclusion, it should be reemphasized that this informed working group, with its diversified representation, provides a means for a comprehensive and expedient solution to the problems of the filtration industry. Their actions have proven invaluable to the industry and are at least partially responsible for the increased performance of the present HEPA units.

REDEVELOPMENT OF THE SAVANNAH RIVER LABORATORY MOISTURE RESISTANCE TEST FOR FILTER PAPER

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ABSTRACT

Important users of HEPA filter media for reactor containment specify exposure of filter media for 10 days to a steam-air mixture to guaranty freedom from breaks in the media in actual filter installations. This test was found to be superior to the current water repellency test adopted in 1956. This paper describes a redeveloped test of 2 hours duration in an apparatus modified by the Savannah River Laboratory. A new method to assess changes in elasticity was introduced. Two transducers of the Sonic Modulus Tester are mounted on the inside of the exposure chamber and contact the filter media.

INTRODUCTION

At the Air Filter Meeting in Boston, Massachusetts on September 14, 1966 during the 9th U. S. Atomic Energy Air Cleaning Conference, the Herty Foundation, Savannah, Georgia was asked to redevelop the Savannah River Laboratory test.

Albert H. Peters and three coworkers described in DP 812 their pioneering studies. (1). They designed a small-scale apparatus with a nominal flow-rate of 5. 78 liters/min. and a large test facility with a nominal flow rate of 1000 scfm for use in acceptance testing of commercial HEPA filters.

C. A. Burchsted in a summary of the Air Filter Meeting dated October 21, 1966 listed comments by manufacturers of filter media and filters. (2) The current Savannah River Laboratory acceptance procedure consumes too much time (10 days) and the cost for labor is high. It was estimated at $1500. C. A. Burchsted stated that... "these tests are probably sufficiently severe to screen out filter papers and constructions subject to failure due to insufficient moisture resistance." Burchsted mentioned three major aspects of the moisture problem:

1) Plugging of the filter by entrained moisture or condensed steam with resultant increase in pressure drop and subsequent loss of filter efficiency or rup ture of the filter. This is directly related to water repellency.

2) Loss of wet strength of the media when exposed to steam or sensible moisture due to leaching of the waterproofing.

3) Long term deterioration of the filter media when exposed to occasional high humidity, steam or entrained moisture.

The assignment to the Herty Foundation was clarified in several meetings with A. E. C and S. R. L. representatives (letter received on June 10, 1968.) It was described as the, "Redevelopment of a standarized accelerated steam air test of water repellent media of high wet strength for high efficiency particulate filters."

OBJECTIVES

A filter media of known performance quality was to be exposed for at least 60 minutes to allow time for penetration of water. Preferably another hour was to be consumed to obtain sufficient plugging of the media with water to obtain rupture. Then a slightly milder procedure was to be found. It was to be close to the severe condition which had caused ruptures of 0.5 - 1.0 cm in length within the fold. This single fold in the cross direction of the media was to be made in accordance with MIL F 51079 item 4.6.5.2. This milder procedure which did not rupture the reference sample was to be applied to the other five filter media which had been sent to Herty Foundation. S. R. L. suggested that the rate of water plugging and the final pressure drop across the filter media be determined. Herty recommended the determination of the sonic modulus to monitor items 2 and 3 in Burchsted's listing. The sonic modulus measures basic material properties similar to the Young's modulus of elasticity but is a non destructive test.

The D. O. P. penetration of the untreated paper was to be compared with D.O.P. tests on exposed paper still wet. The Tensile Energy Absorption Test (TAPPI Standard T494 su-64) was recommended by Mr. Heyse. It was applied on filter media which were tested for wet strength under conditions closer to the steam air test than proposed in MIL-F 51079 item 4. 6. 3. Herty added the determination of the Young's Modulus of Elasticity since recent research shows far better correlation of a modulus value with actual usage than other tests.

The report DP 812[1] contained on page 18 one sentence, "Small-scale tests do not reliably predict the performance of full size filters . . . " Therefore, a redevelopment of the small-scale apparatus became necessary.

RESULTS

1) The redeveloped steam air test applies a steamblast for 15 - 30 - 15 seconds at 10 fold normal rated flow to test the adhesion of the water repellent agent to the fibers. This is followed by a flow of 4. 5 times normal rated flow for 2 hours of a mixture of 18 liters of air at 25° C. and 7. 85 liters of saturated steam at 101° C. with a mixture temperature of 65° C. These conditions are close to the slightly more severe exposures which cause rupture of the reference sample in the cross direction fold line. Figure 4 shows the curves for the increase in ΔP or the pressure drop across the filter in inches of water gauge.. When plotted against exposure time the five filter media vary somewhat as shown in the shape of the curves. Their maximum ΔP value has a range from 7. 7 to 10. 0 inches of water. Table I lists all physical tests and shows data for the additional sample No. 6 which is a non waterproofed filter media. Its ΔP rose quickly to 15 1/4 inches and the sample ruptured in 5 minutes.

2) Table II shows that good replication can be obtained.

3) Two tests were made over a 2-day period simulating the original procedure of exposure for 10 days. Correlation with the proposed 2-hour test seems to exist. No direct comparisons to 10-day tests on commercial filters have been made.

4) All available filter media could be ruptured within two hours by an increase in steam air volumes. A similar wet burst test reported in the original DP 812 work showed such testing to be unsatisfactory. Filter media A and B were found to be alike in such rupture tests while B failed and A passed in the steam air test for 10 days.

5) Three aspects of the moisture problem were outlined in the introduction. In addition to the degree of water repellence indicated by the ΔP versus time curves the resistance of the filter media against steam air deterioration must be determined. The change in Young's modulus of elasticity in destructive tensile testing before and after steam air exposure or of the Sonic Modulus in dynamic non destructive testing can be used. The Pulse Propagation Meter has a Planar Mount on top of the instrument. The filter media of 3" diameter with the one C. D. fold line can be tested within a few minutes on this table. Tests before and after steam air exposure have been made. Since a sample removed from the exposure chamber looses temperature and moisture rapidly, it is helpful to

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TABLE I
PHYSICAL TEST DATA

Item							
1	Sample Designation	1	2	3	4	5	6
2	Basis weight 24"x36"-500	62.4	59.1	47.7	52.3	56.4	51.5
3	Caliper (TAPPI), inches	0.0185	0.0177	0.0208	0.0126	0.0146	0.0168
4	Caliper (Microscope), inches	0.0236	0.0252	0.0244	0.0199	0.022	--
5	Caliper Conversion Factor	1.275	1.42	1.17	1.58	1.51	--
6	Apparent Specific Gravity g/ml	0.169	0.150	0.126	0.169	0.165	0.157
7	Pressure Drop water, inches	10	9.8	9.45	7.7	9.35	15.25
8	Water pick up, %	89	102	200	70	64	460
9	D.O.P. penetration before exposure, %	0.048	0.068	0.062	0.090	0.070	0.076
10	D.O.P. penetration after exposure, %	0.052	0.08	0.04	0.086	--	--
11	Sonic Modulus, dry, psi	2650	2675	2020	1850	2750	1210
12	Sonic Modulus, Exposed, psi	1465	1700	860	985	1720	240
13	Strength retained, %	55.3	63.6	42.5	53.3	62.5	19.8
14	Tensile, folded, soaked 65°C., lb/inch	1.25	1.06	1.0	0.38	0.60	0.21
15	Elongation in %	0.86	1.2	0.33	2.3	1.85	1.35
16	Tensile Energy Absorption ft. lb/ft^2	32.35	31.8	8.55	9.41	20.9	8.11
17	T.E.A. in Modulus area	20.1	22.1	6.24	3.6	2.8	3.65
18	Modulus - Slope - lb.	37.9	21.1	79.5	6.6	25	11.6
19	Young's Modulus, psi	800	420	1625	167	570	277
20	Pierce Test, grams	60	100	80	36	--	--

TABLE II

DEGREE OF REPLICATION

STEAM AIR TEST

Interval in Minutes	Morning Period ΔP	Afternoon Period ΔP in inches of water
Steamblast 0.5	3.5	3.5
Steam Air 14	3.75	3.75
" " 44	4.0	4.0
" " 64	4.25	4.25
" " 84	4.5	-
" " 94	-	4.5
" " 108	4.75	-
" " 116	-	4.75
" " 119	4.87	5.0

determine the moisture content of exposed media before and after the Planar Mount Sonic Velocity Test. Higher moisture content produces a higher reading on the micro second scale which records the time for the sound to travel a known distance. However, upon a graphical correction of the times for two different distances and deducting the, thus found, "zero intercept delay" it was shown that the mechanical wave travels through the solid material as claimed by Craver and Taylor.[3] Therefore, the sonic velocities are very similar, at least for a few media which were thus evaluated. The moisture contents varied from 80 to 100% based upon the air dry weight of the sample prior to the steam air test.

6) The transducers can be mounted within the steam air exposure chamber downstream from the filter media if a special support plate and neoprene gaskets above and below the media/ are used. This prevents erroneous travel paths for the mechanical waves. The transducers are sensitive to wet steam and must be protected by a novel rubber shield of about 5 mil thickness. Thicker and certain rubbers give uneven signals or none at all. The sonic modulus when measured on the filter media while it is hot, stressed and bulged is more instructive than the Planar Mount test outside when the media has cooled and recovered and appears to be a flat sheet.

7) Figures 6 and 7 show stress strain curves obtained on a calibrated Instron Tensile Tester operated in accordance with specifications found most suitable by the Naval Research Laboratories. The Instron Tests were made with strips 6" by 2" folded according to MIL:51079, then soaked in hot water at 65° C. for 2 hours. This wet tensile of a folded strip had a tensile of 1.06 Kg/2 inches in comparison to the wet tensile of a non folded strip soaked in cold water of 1.81 Kg or a loss of 41.7%. The more severe test is similar to the steam air test by this soak at 65° C. These Instron graphs show remarkable differences in maximum tensile, elongation and in over all shape.

8) The Tensile Energy Absorption values were determined as usual for the total area. (TAPPI Standard T494 su-64.) In addition the T.E.A. area was measured under the initial slope as used for the Young's modulus. The data are listed in Figures 6 and 7 and in Table I.

9) Young's modulus of elasticity has been found to provide far superior correlation with the actual behavior of shipping containers than all the many other tests.[4] In the case of the soaked filter media some uncertainty existed in the selection of the initial straight elastic part of the upcurve. The calculated slopes are shown in Table I. Young's modulus is obtained from the slope and the cross section of the sample. TAPPI thickness test compresses filter media to a varying degree as shown in Table I. Therefore, the uncompressed thickness of the filter media as determined under a microscope was used for Young's modulus.

10) The sonic modulus was calculated by Craver and Taylor from the solid fiber density. The literature gives a density of 2. 54 for glass fiber. Previous authors used apparent specific gravi ty for filter paper and its use for filter media seemed to be better. Again uncompressed thickness was applied.

11) D. O. P. penetrations on the 6 media before and after exposure were determined. Tests on media of about 100% moisture resulted in bad fluctuations on the Per cent Penetration Indicator Meter caused by water droplets accumulated in the scattering chamber. This made it necessary to recondition the scattering chamber before further use.

Several tests were made on exposed filter media after they were dried to a water content of 40%. Only slight changes in D. O. P. were noted and are listed in Table I. It required a single puncture by a needle with a tip diameter of 27. 5 mils to increase the D. O. P. penetration about 10 fold. Such single pinpoint failure did not occur up to now. The actual ruptures were of 0. 5 to 2 cm. length within the fold, whereupon the D. O. P. penetration became very high.

12) The British Pierce Test is mandatory in the "Specifications for all Glass Fibre Paper Filtering Medium before Assembly." [5] It was modified for use on wet exposed filter media. The load in grams to pierce with a needle of . 025 inches in diameter ranged from 16 grams to 108 grams.

13) Evenness of the fold lines of filter media varies. Experience with envelope and other papers indicates that possible improvements might be feasible either in the manufacture or in better folding of the filter media.

14) Inspection of the ruptures showed up structure weaknesses as shown by delaminations of layers.

15) S. R. L. designed a new steam inlet plate with the objective of feeding steam or steam air parallel to the media. Then to pass in a narrow space normal to the media. New piping, needle valves, thermo couples were received. These controls, together with very uniform temperature of the air (25^{o} C.), its volume and uniform quality of the steam, are required to obtain a dependable increase in ΔP of the filter media.

16) The Lucite plate at the front end when coated with "Fog Pruf" repellent made it possible to observe the media during exposure. The slight deformation of the media by the transducers towards the upstream side and the downstream bulging of the media in the unsupported rectangular area could be observed. The separation of a paper layer next to the wire side indicated early rupture. This non representative sample was replaced by another sheet which did not fail in this test.

CONCLUSION

The redeveloped steam air test monitored by either Sonic Modulus or Instron Modulus was applied to 6 filter media. It appears to provide useful information.

DISCUSSION

Figure 1 shows the general layout of the apparatus and on the right side, the new steam inlet plate, all designed by S. R. L.

Figure 2 is a photograph of the support plate for the filter media. The supplier of the Dynamic Modulus Tester removed the aluminum rods from the "Holder" shown in Figure 7 of report DP 812 (page 47) since interference with wave propagation was expected. The rods were replaced with a stainless steel plate drilled with larger openings for steam air passage and small holes to insert plastic tubes to prevent contact with the metal. Experiments proved that with this support rupture of media would be obtained only at very high ΔP and after a long time.

Complete removal of the support plate accomplished the opposite result, since media would now rupture in a few minutes at low ΔP. Then a rectangular area approximately equivalent to the open area in the original holder was cut out. The transducers were mounted at first above and below the C. D. fold line. If a rupture occurred just in the line of the transducers, the sonic signal changed. However, a rupture to the left or right of the transducer line was not detected. Finally, the fold in the media was aligned horizontally with the long axis of the rectangular open area and the transducers were mounted in the fold line on either end. The fold was made by placing the rod 1/16" diameter on the wire side. The wire side was mounted upstream. This placed the transducers onto the felt side.

The WTRT-5FBIC Transducer with a ceramic crystal worked well for a few weeks and then failed. Recoating with plastics helped for a while. The best protection was accomplished with a finger-cut piece made from neoprene rubber of 5 mil thickness as suggested by the Morgan Company.

At the start of the test the transducers are moved on a support rod to a separation of 4 cm. Upon completion of the steam air test they are moved inwards to a distance of 2 to 3 cm. which must be measured when the apparatus has been opened after the test. Two measurements of the wave travel time–one at 4 cm. and the other at any smaller distance, suffice to plot a straight line which at the intercept with the ordinate gives the "zero intercept delay." This correction is subtracted from the micro seconds read on the instrument chart for the distance of 4 cm.

The steam air test is started by preheating the whole equipment. Then the support plate with the filter media enclosed in two rings of 1/32" thick

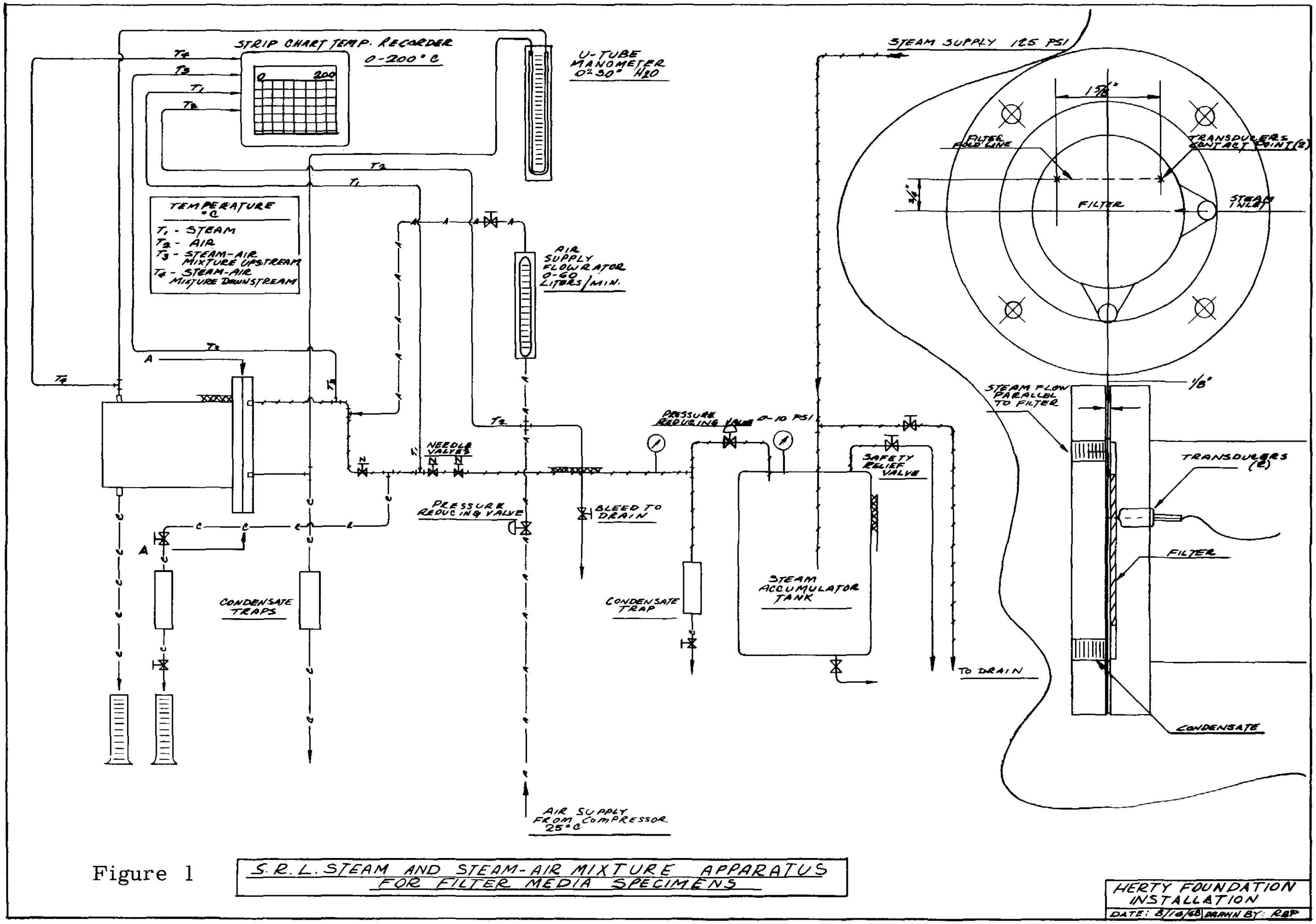


Figure 1 S.R.L. STEAM AND STEAM-AIR MIXTURE APPARATUS FOR FILTER MEDIA SPECIMENS

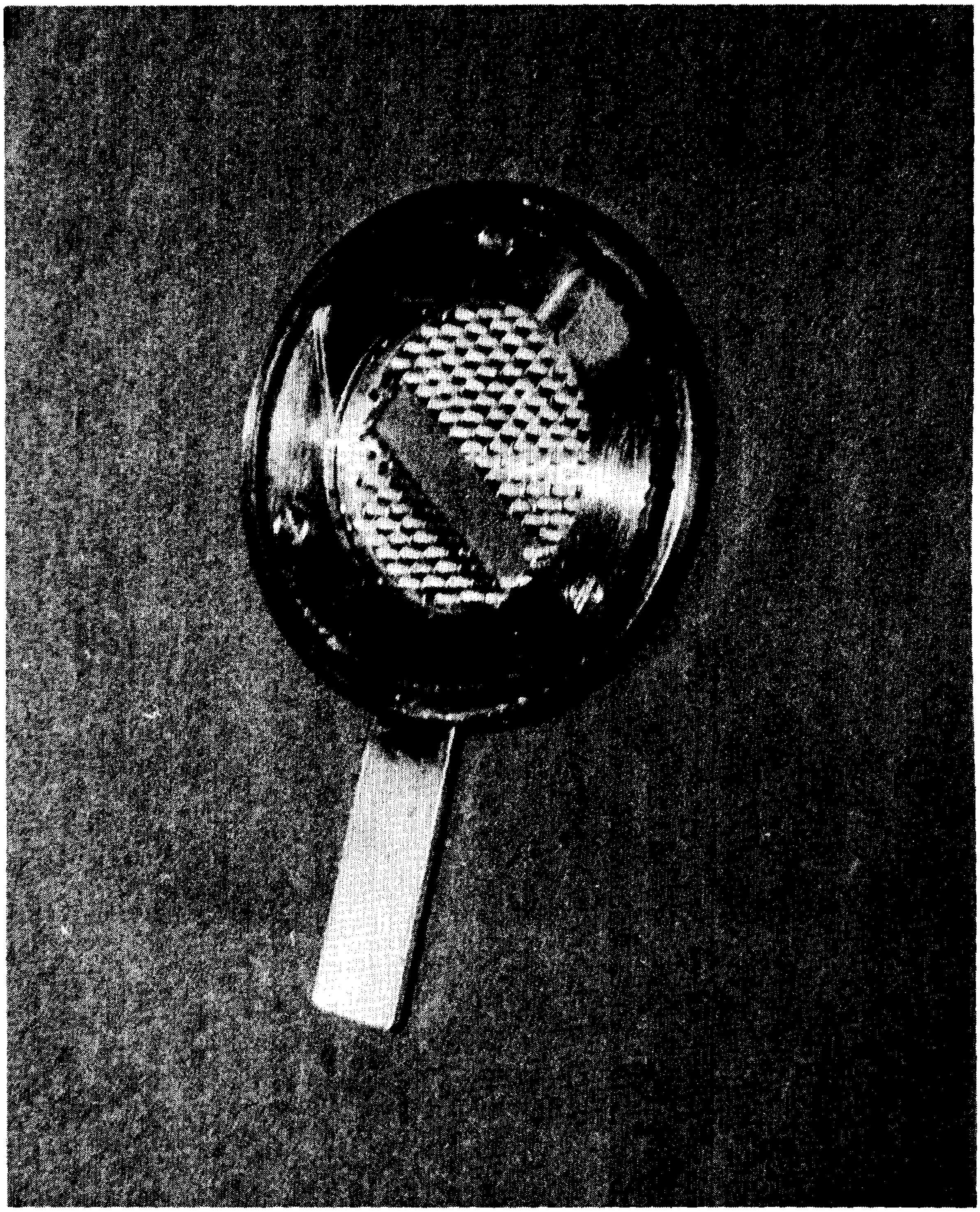


Figure 2 Steam-Air Sample Support

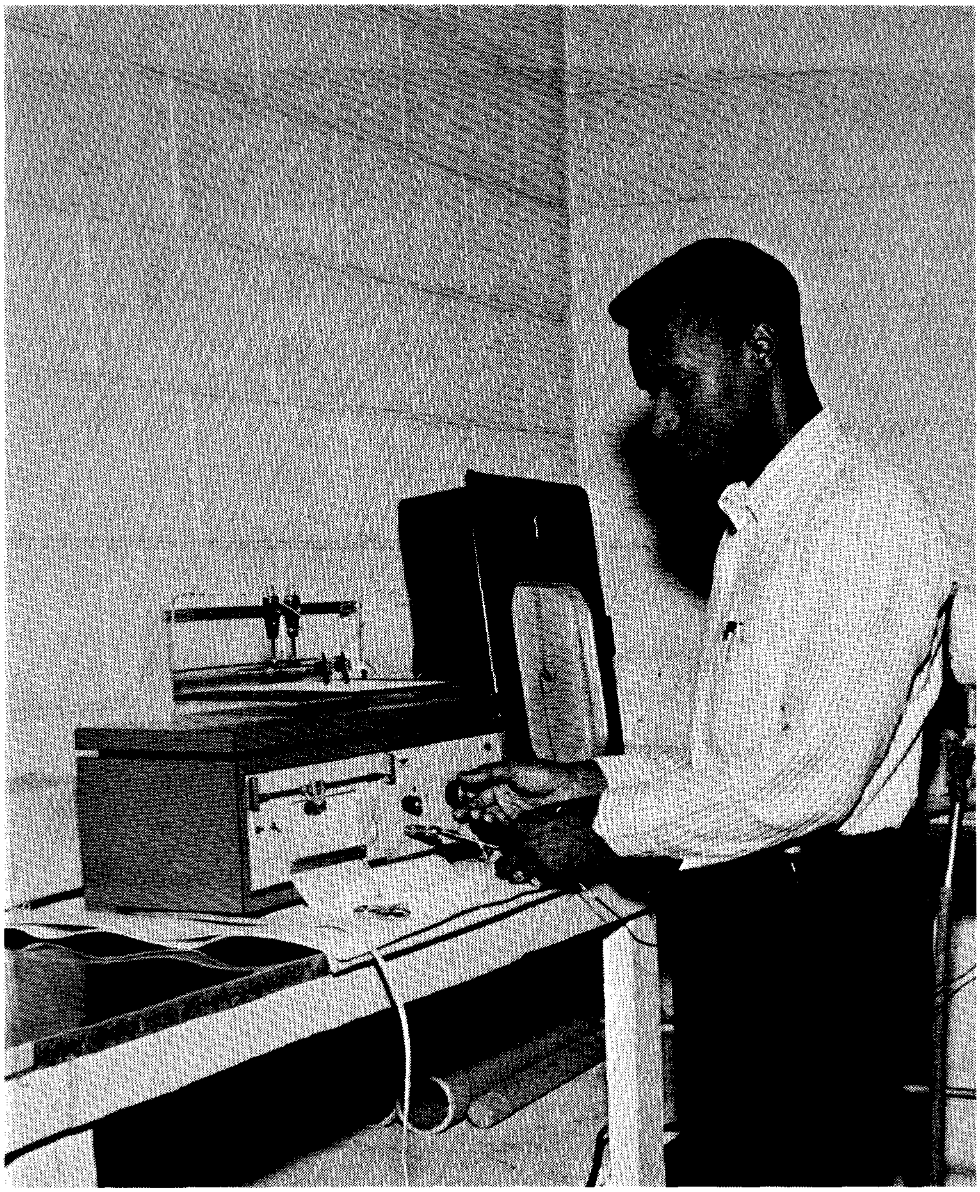


Figure 3 Sonic Modulus Test

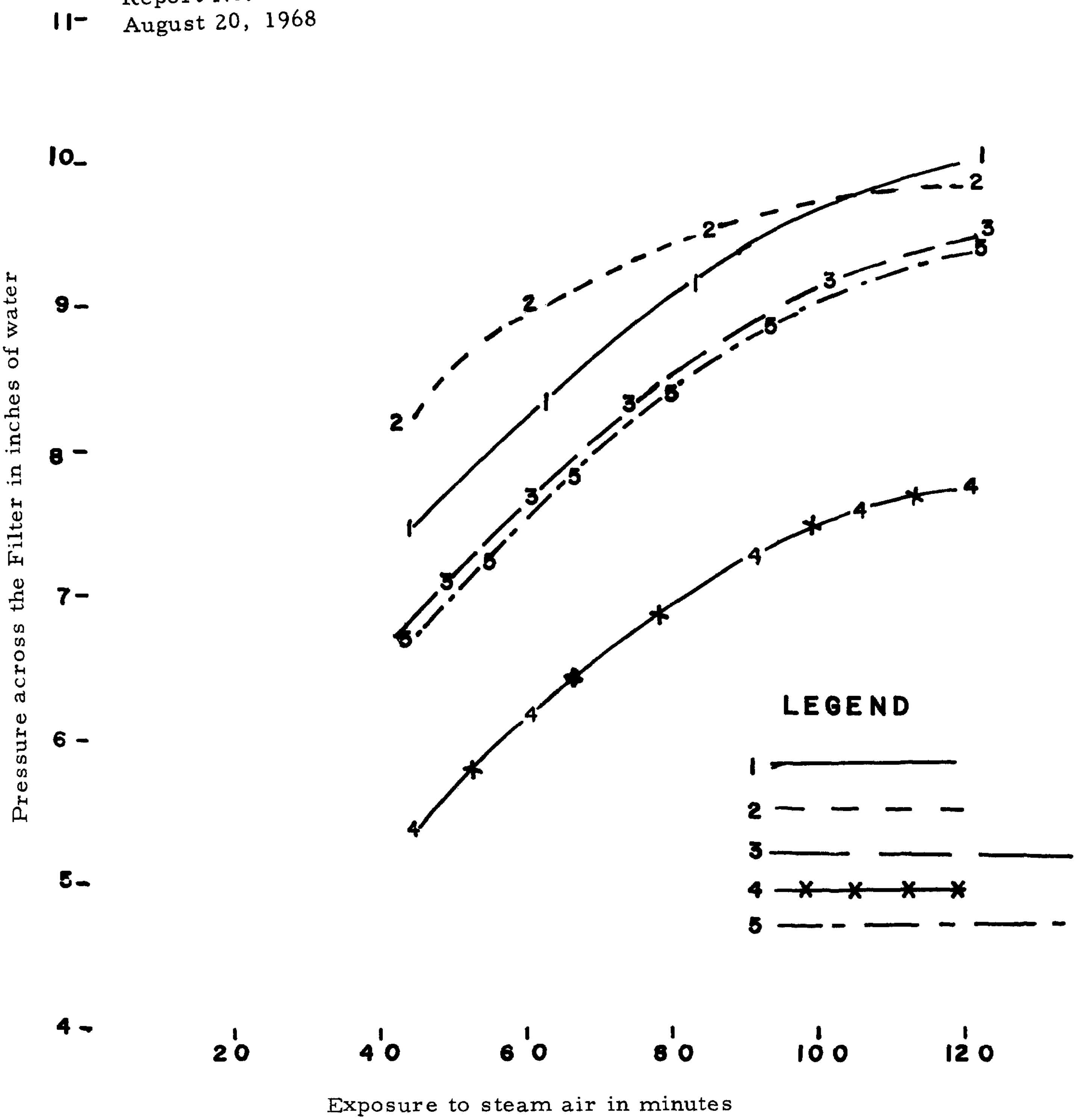


FIGURE 4 PRESSURE DROP ACROSS FILTER VS EXPOSURE TIME

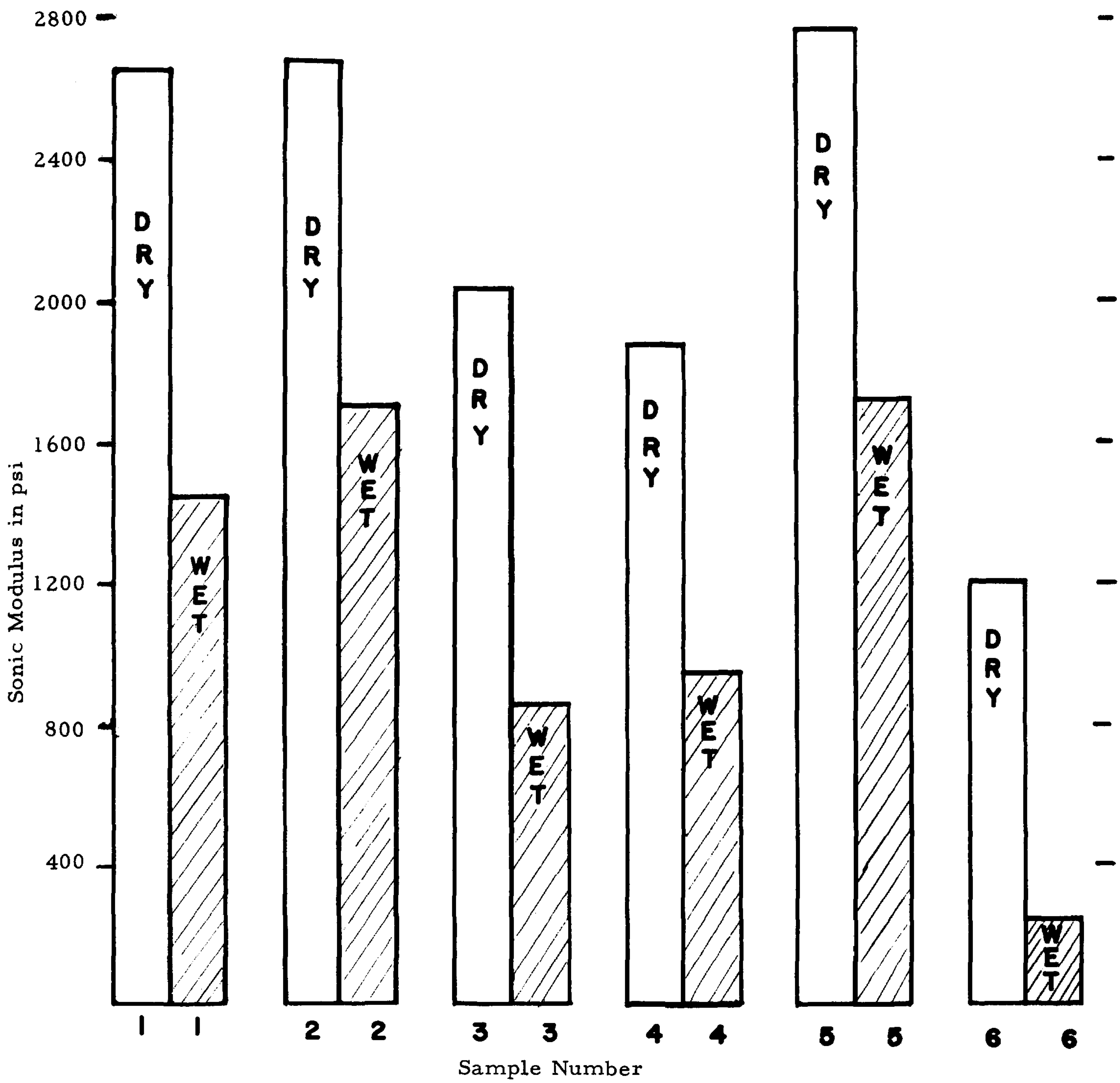


FIGURE 5 EFFECT OF STEAM AIR EXPOSURE ON SONIC MODULUS

Instron Tensile in Kg and Elongation in %
Crosshead Speed 0.127 cm/minute
Chart Speed 10 cm/minute
Samples folded, soaked 2 hrs in water of 65° C.

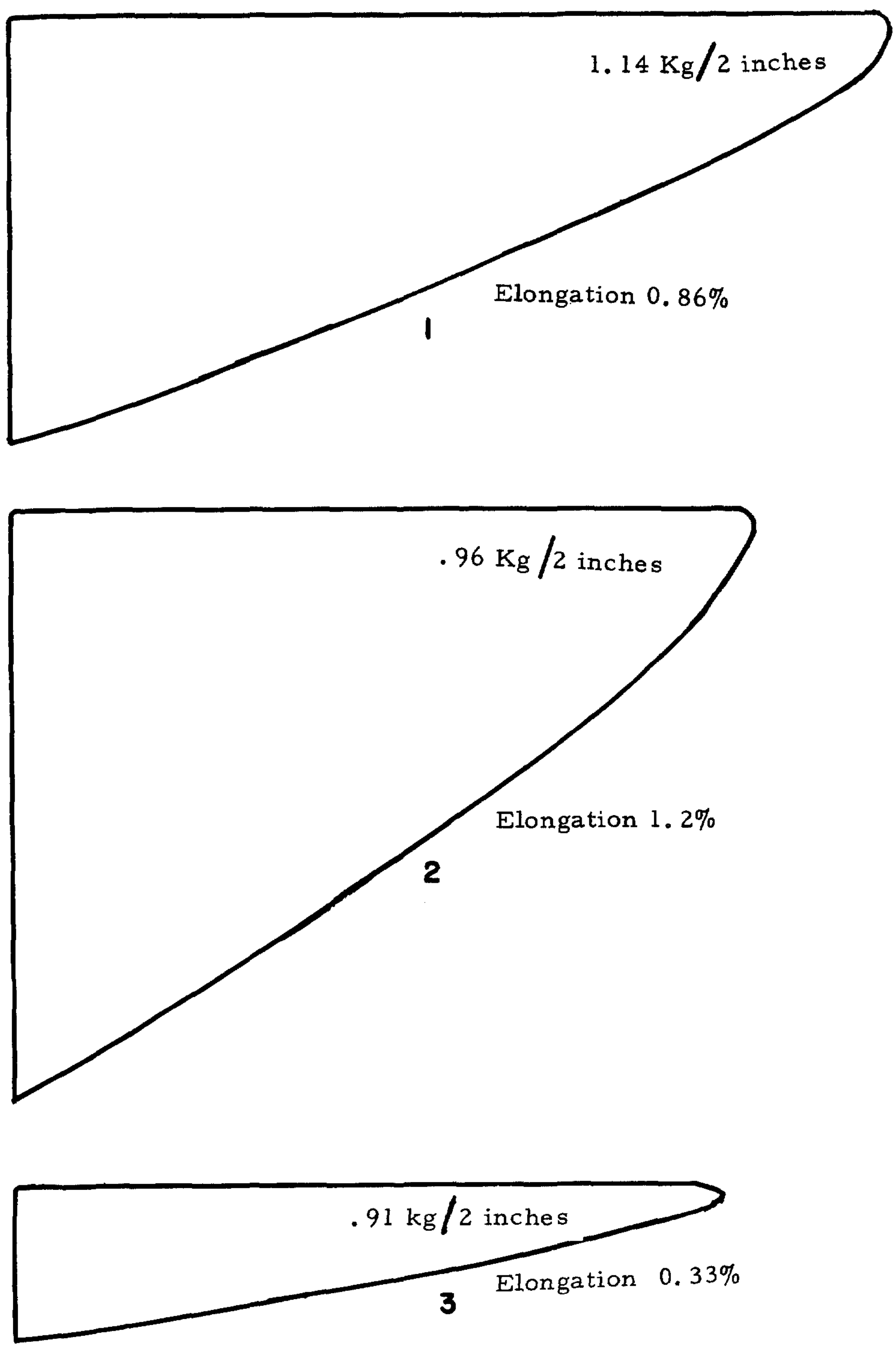
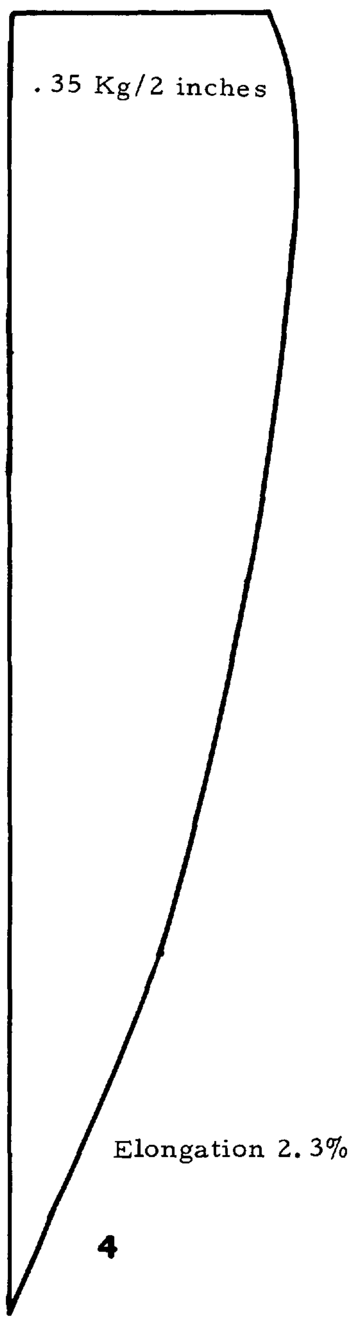
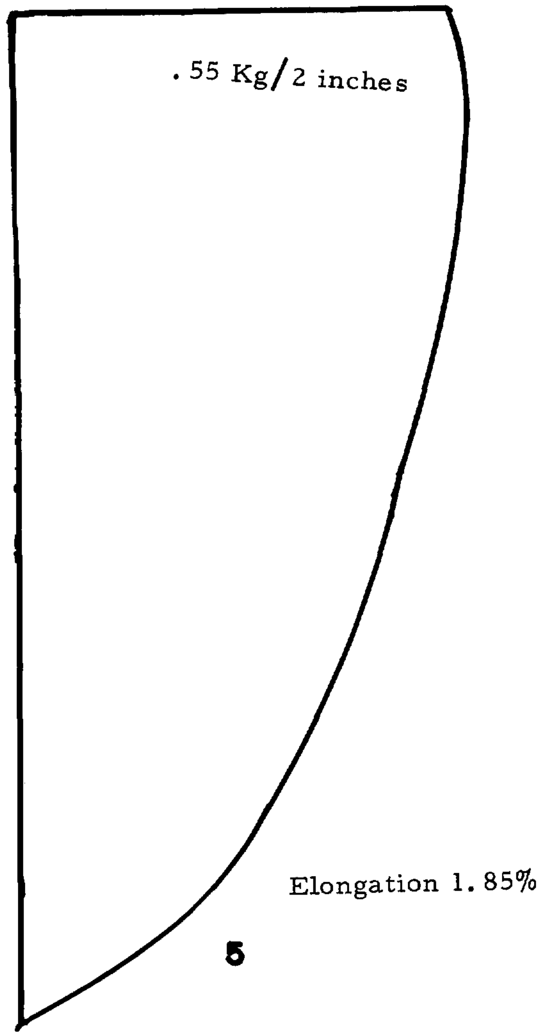


FIGURE 6 TENSILE ENERGY ABSORPTION





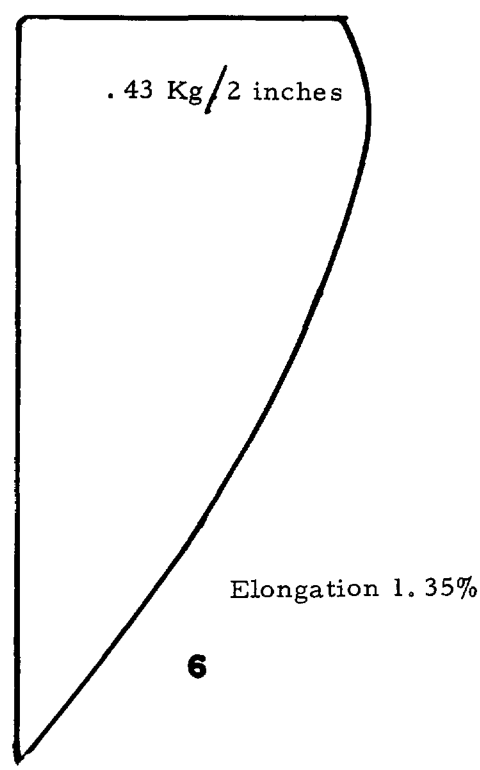


FIGURE 7 TENSILE ENERGY ABSORPTION

Figure 8 Uneven Fold Line Photographed at 12X

neoprene gaskets and the steam inlet plate on top is inserted into the apparatus and tightened with bolts to prevent leakage of steam. The steam blast of 55 liters per minute is regulated to take 15 seconds to open the needle valve to its correct position. Then the blast, itself, lasts 30 seconds and the closing of the valve is again controlled to 15 seconds. The valve setting was obtained in a calibration test by condensing the steam and weighing of the condensate. During the unusually hot Savannah summer it was at first very difficult to maintain the air temperature at 25° (plus or minus 0. 2° C.) Herty supplied a dependable solution by feeding air through a room air conditioner. The water content of the steam must not vary. Therefore, any cooling of the steam in a colder room had to be prevented. Coarse entrained water particles were removed in the steam accumulator tank. The four thermo couples were found to be very helpful in obtaining chart records on a potentiometer for the temperature of the steam (T_1), air (T_2), upstream mixture (T_3), and downstream mixture (T_4). A hand thermometer is used to control the temperature inside of the insulated enclosure to match the downstream temperature.

A rotometer, slightly larger than required now, is used to measure the volume of air. The steam flow in the steam air mixture was calculated by S. R. L. from the thermodynamic properties of the mixture (Fig. #2 of D. P 812, p. 42.) A modified graph was received from S. R. L. on June 10, 1968 for conditions of the Herty installation. It showed that for steam initially saturated at 14. 7 psi and ambient air of 25° C. and 50% relative humidity, the normal rated steam air flow for a mixture temperature of 65° C. should be 5. 78 liters/min. The air flow should be 4. 03 liters/min. and the steam flow 1. 75 liters/min. for a sample 3 in. in diam. This is equivalent to a flow of 1000 cfm for a 24"x 24" full-size filter with a filter area of 240 sq. ft. The graph showed that 0. 65 lb. of liquid water would be entrained in 1000 cfm of the steam air mixture. The setting used on the rotometer indicates approximately 18 liters of air or 4. 47 times the rated flow for the 3-in. sample. Therefore, a steam volume of 7. 83 liters/min. is needed. As a check on this volume the steam air mixture which passed through the filter media was measured. Results were as follows:

Time Interval	Steam Liters/Minute
1st to 11th Minute	6. 9
12th to 38th Minute	6. 5
39th to 64th Minute	6. 15
65th to 90th Minute	6. 09
91st to 120th Minute	5. 97

The steam removed as condensate at the steam air inlet should be added.

Data in Table II show that the curve for Δ P versus time presented in Fig.4 can be closely duplicated. In case of difficulties it is helpful to retest a reference sample.

Sonic Velocity - Dynamic Modulus Measurements.

The older procedures to apply the velocity of sound for investigations of rayon or nylon yarns and of regenerated cellulose films were much improved by Hamburger (6). In the new technique short-lived pulses of sound were sent into the test filament. The time required for the pulses to travel a known distance yielded a sonic velocity which was directly related to the instantaneous extensional elastic modulus (Youngs' Modulus).

Taylor and Craver (3) and (7) reviewed other investigations and noted that this valuable technique had not been applied to paper in spite of the successful application of sonic pulse velocity to the study of synthetic fibers. Horio and Onogi measured the dynamic Young's modulus of papers by the vibrating reed method (8). Sève, Perrin, Kubat, Nyborg, Steenberg used similar procedures in studies of paper elasticity.

Craver and Taylor selected the sonic pulse velocity technique as a non-destructive, rapid, continuous test, while the specimen is undergoing change either from external mechanical stresses or from attack by penetrating fluids. The principles involved and basic applications were discussed (3). The theory of anisotropic elasticity is examined in their Cambridge paper (7). The "Sonic Velocity Response of Wet Strength Paper" was presented at the January 1966 meeting of the Canadian Pulp and Paper Industry (9). Craver presented a review at the August 1968 Gordon Research Conference.

Craver and Taylor and the authors of later papers used the Dynamic Modulus Tester PPM 5 R (10) which is based on S. R. Rich patent (11). Relationships between fibrous structure and properties such as stiffness, elasticity resilience and state of fatigue can be established. The modulus of elasticity can be derived from the data generated by this compact tester in modular construction of solid state circuits. The pulse propagation meter brings a piezo-electric element resonant at about 10 kc into contact with a paper sample of 1 inch width or of a disc of 3 inches in diameter. It is shocked into vibration parallel to the plane of the paper by a 5 millisecond voltage pulse which simultaneously activates a timing circuit. The mechanical wave travelling through a measured sample distance is detected by a second transducer. Distance in kilometers divided by travel time converted from microseconds into seconds gives the value for sonic velocity with the symbol "c". The square of the sonic velocity c^2 is proportional to the elastic modulus. A Youngs Modulus E is obtained by multiplication with a factor of 1.45 times 10^5 and with the density of the paper to yield a value of E in psi. Multiplication of c^2 by density and a factor of 10^{10} yields E in dynes per square centimeter. As discussed earlier Craver in 1964 preferred the density of the solid material such as glass of 2.54, while Horio and Onogi (8) in 1951 used apparent specific gravity for filter paper. Craver and Taylor in their investigation of Sonic Velocity Response of Wet Strength Paper (9) used the sonic velocity c^2. The Cambridge paper by Taylor and Craver

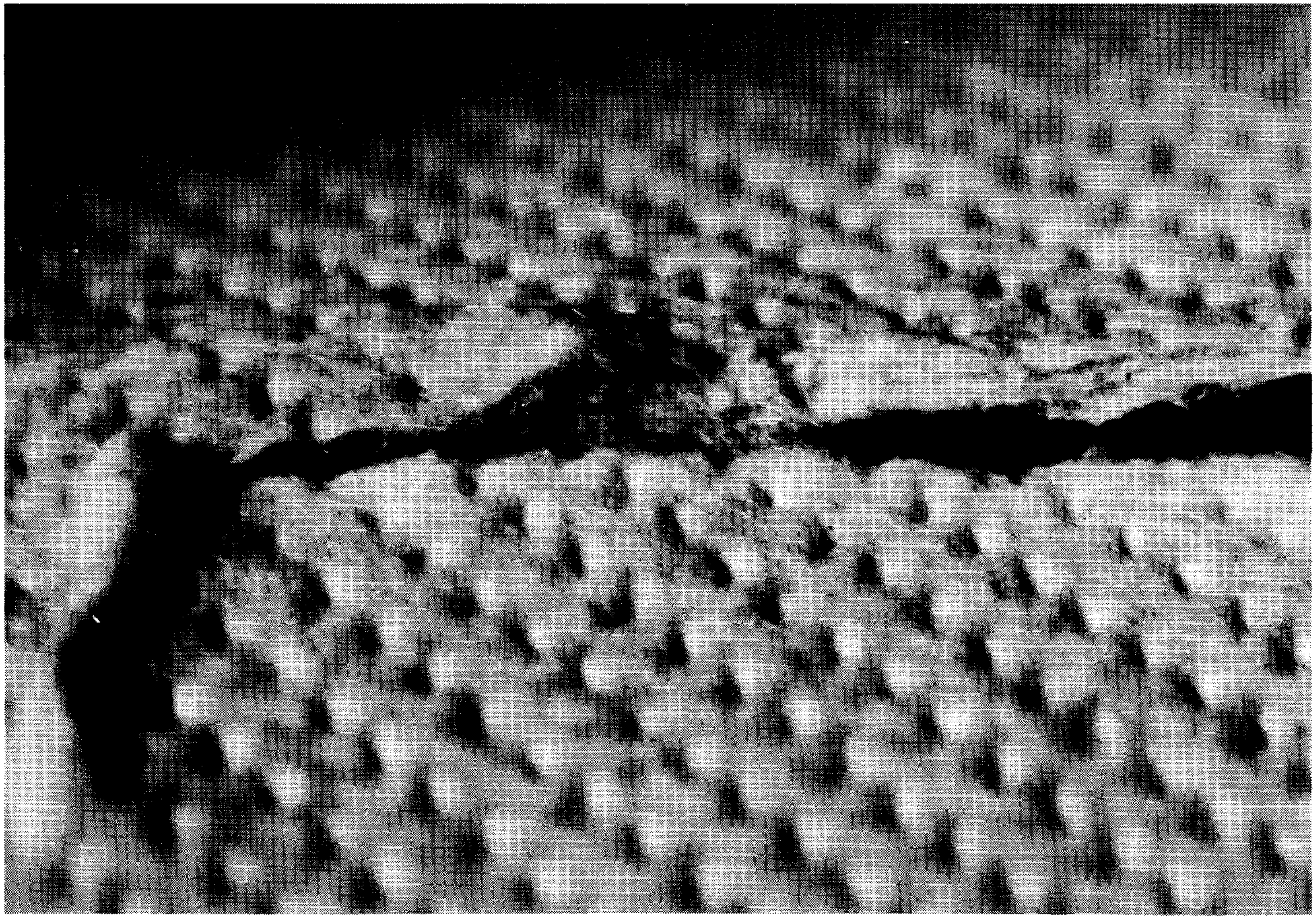


Figure 9 Uneven Fold Fracture and Delamination Photographed at 12X

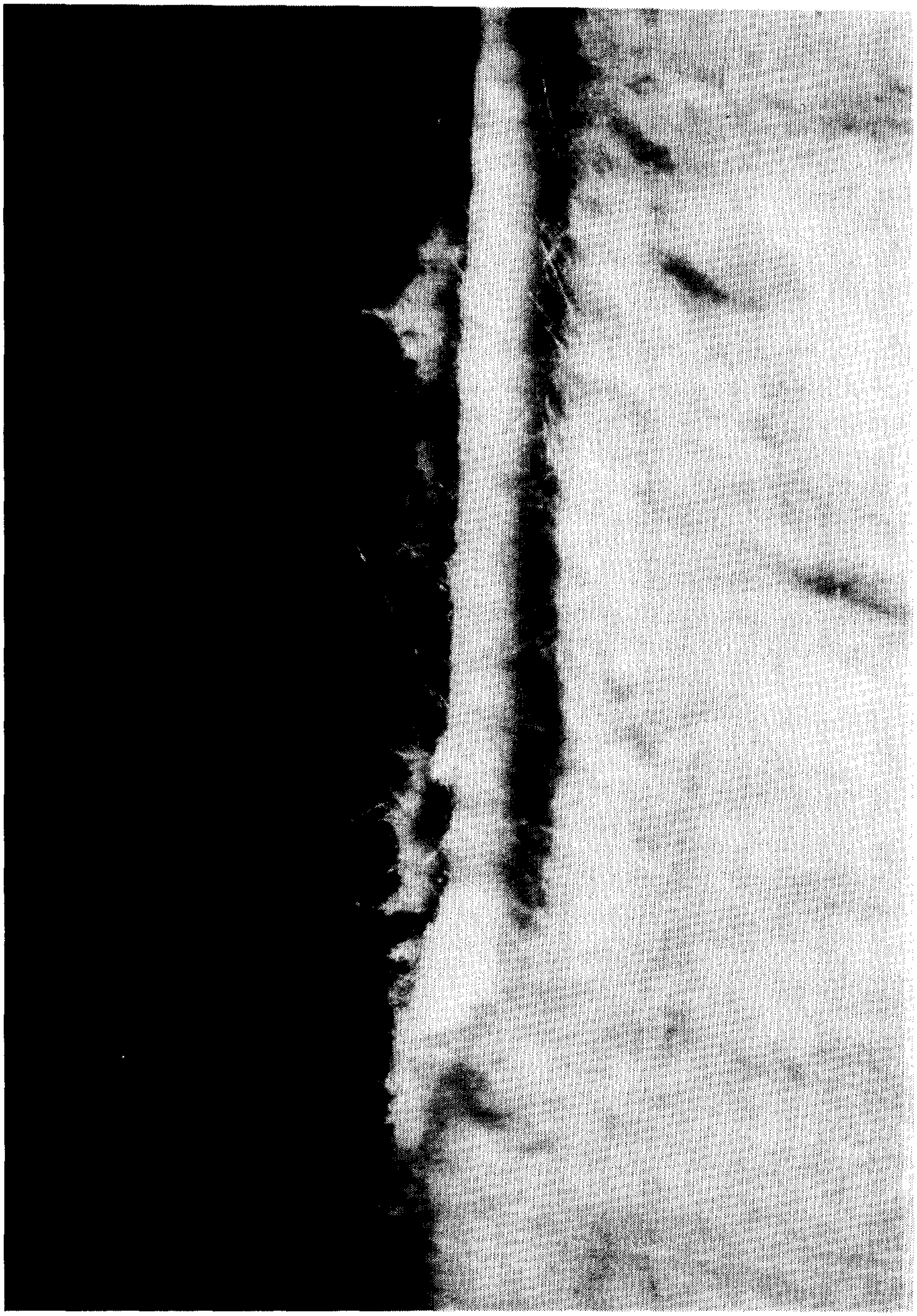


Figure 10 Edge View of Fracture Photographed at 12X

mentions a difference between well bonded paper and loosely bonded filter paper. A "True Apparent Density" in g/cm^3 is used to calculate Young's modulus from sonic velocity data. The data in this report are calculated with a true apparent density.

Yiannos of Scott Paper Company (12) found a good correlation of tensile and sonic velocity. "Perhaps the two most valuable measurements for wood are sonic velocity and bulk density."

Jackson and Gavelin (16) obtained in kraft paper a more precise modulus of elasticity from sonic tests than from the initial gradient of the stress strain curve.

The research group at the Swedish Wood Research Centre (18) concluded that "the ultrasonic pulse velocity technique for determination of Young's modulus of elasticity provides a useful tool..." The modulus of elasticity decreased at certain temperatures between 50°C to 240°C due to thermal softening but increased at 300°C due to thermal hardening.

Houen, in a Norwegian Thesis (19) observed a "linear correlation with dynamic modulus and the number of fibers broken in rupture zones. Sonic velocity measurements were satisfactory".

Becker (20) in a German investigation compared Young's modulus and the sonic modulus.

It can be concluded that the sonic velocity tests are dependable and often superior to tensile tests. It is rather difficult to obtain reliable stress strain data on the very fragile 6" by 2" folded, hot, wet strips of filter media. It is far easier to make sonic test on a media which was placed into a holder prior to steam blast and steam air tests.

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FACTORS INFLUENCING HIGH EFFICIENCY FILTER GASKET LEAKAGE

By

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ABSTRACT

Data are presented on the performance of molded polyvinyl chloride HEPA filter gaskets. Tests show their overall performance poorer than the closed-cell neoprene gaskets presently in use. The molded gaskets do not seal adequately around defects in mounting surfaces. They also have a tendency to deform permanently by shearing at compressions above 35%. Recommendations are made for specifying HEPA filter gaskets based on this report and previous reports.

INTRODUCTION

This report describes the findings of a study of the sealing properties of various high-efficiency, particulate, air (HEPA) filter gaskets. The work described is a continuation of a previously reported study. 1/ The primary purpose of this concluding phase was to compare the performance of molded one-piece solid polyvinyl chloride gaskets with closed-cell neoprene gaskets having jointed corners.

The development of HEPA filters has led to filtering efficiencies on the order of 99.97%. Thus, since such efficiencies for the filter medium are commonplace, it is important that the structural components of the filter assembly complement the efficiency of the medium. The filter medium must be free from flaws and must be cemented firmly to the frame. The frame itself must be free of defects that could cause leakage around the medium. Finally, the gaskets between the filter frame and the mounting surfaces must provide satisfactory sealing around any irregularities in the mounting surfaces.

1/ F. E. Adley, Progress Report: Factors Influencing High-Efficiency Gasket Leakage. HOHF-1. Environmental Health Sciences Dept. Hanford Environmental Health Foundation, August, 1966.

Preliminary investigations of the problem of finding an ideal gasket identified the following areas requiring further study:

1. The effect of aging on gasket leakage.

2. The effect of high compression on gasket materials.

3. The importance of gasket skin surfaces.

Included in this report are studies related to:

1. The effect of skin surfaces on gasket sealing properties.

2. The effect of high compression and aging on solid molded gaskets.

3. General leakage performance of solid molded one-piece gaskets.

SUMMARY

Tests were conducted to study overall HEPA filter gasket performance with emphasis on leakage and physical properties of the gasket materials.

Leakage tests were performed on a full scale test facility approximating gasket mounting conditions for a 1000 cfm filter. Data on leakage rates were taken at differential pressures between 1 and 5 in. of water across the gasket at compressions up to 40% of the original gasket thickness. Artificial defects were then added to the mounting surface, and another set of data taken to test the effect of the defects on sealing.

In general, the molded one-piece solid rubber gaskets with uniform thickness throughout showed a rapidly diminishing leak rate with increasing gasket compression in tests without the artificial defects. Leakage rates dropped to 10^{-4} cfm at compressions near 10%. With defects added, leakage rates dropped relatively slowly to 10^{-2} cfm at compressions near 20% and leveled out. Further compression to the limit of the test facility did not produce any significant further reductions in the leak rate. It appears that the skin surface on the molded gaskets prevents adequate sealing around defects at low compressions.

Individual molded gaskets with relatively large variations in thickness (0.25 in. ± 0.040 in.) produced considerably greater leak rates than those whose dimensions were more uniform. It was also observed that not only is it the variation in thickness that causes large leak rates but the location of such variations. Gaskets with large variations in thickness at or near the corners have larger leak rates than those with the same magnitude variations located elsewhere along the gasket. This appears to be due to the direction in which the material is displaced under compression.

Several closed-cell neoprene gaskets with corner joints were similarly tested for leakage. Generally, these gaskets showed good sealing properties both with and without artificial defects present. These gaskets had no skin surfaces. Compressions in the neighborhood of 10% were required to reduce leakage to 10^{-4} cfm without defects present and 20% compressions for a leak rate of 3×10^{-3} cfm with defects added.

Elastomers have a tendency to relax with time after compression. As a part of this test, gasket sections were compressed to 35% and left for a period of about 50 days while periodic measurements on gasket pressure were made. The molded gasket sections relaxed to an equilibrium pressure within two or three days of the original compression. Equilibrium pressure was about half of the original pressure.

High compression (35% to 50%) of the molded gaskets produces shearing along one of the gasket surfaces. Usually htis occurs on the surface that would be bonded to the filter frame. This poses a serious problem in that the shear forces in the gasket can force the plies of the plywood frame apart or cause other frame damage. In addition to this, the gasket could tear in such a way as to cause a large leak through the gasket. These problems are not encountered with closed-cell gaskets, since compression does not result in a large material displacement.

TEST PROCEDURES

Leak Test. An aluminum test frame, as shown in Figure 1, was used to measure gasket leakage at various pressures and gasket compressions. The test frame was dimentionsally equivalent to a 1000 cfm filter frame. The frame was suspended and counterbalanced by a weight attached at (A) to provide zero pressure on the test gasket (B). During the test, the gasket was compressed on the mounting plate (C) by tightening the clamping bolts (D). The amount of compression was determined by four dial micrometers which could be read to 0.001 in. Force on the gasket was measured by four platform scales (E). Approximately 1/8 in. above the bottom edge of the frame was a welded aluminum panel which formed an air chamber when the gasket seal was made. Gasket leakage was measured by metered air makeup air introduced at (G). Air pressure in the chamber was measured at (H).

Four artificial defects (Figure 2) were inserted between the gasket and the mounting surface to test the ability of each gasket to seal around imperfections in the mounting surface. The defects were about 0.04 in. high and 0.18 in. wide at the base. Data are presented for each gasket with and without defects.

Relaxation. To measure the relaxation of a section of gasket material with time, samples were compressed 35% in a modified compression-set device with the spring removed (Figure 3). Periodic measurements were made of the amount of torque necessary to barely move the nuts. The set-up for doing this is shown in Figure 4. Weight was added to the bucket (C) until the nut (B) started rotating. The amount of weight added at (C) was related to the gasket pressure.

Destructive Testing. It was noted early in the testing that when the molded gaskets were compressed above 35%, they showed tear marks due to shear force. Further investigations of this problem were carried out by clamping samples of gaskets between metal or glass plates.

TEST RESULTS

Leakage. Leak tests were run on each gasket at pressure differential between 1 and 5 in. of water and at various compressions. Low compressions sealed surfaces adequately when the gaskets had a uniform thickness and artificial defects were not present. Introduction of artificial defects increased the compression necessary to reduce gasket leakage. In some instances, satisfactory sealing was not accomplished at gasket compressions attainable with the test set-up. These failures were due primarily to non-uniformity of gasket thickness.

Figure 5 shows the typical relationship between compression and leakage for a closed-cell neoprene gasket with dovetail type corner joints. Without defects, a leak rate of 10^{-4} cfm can be maintained with a compression of 10%. Adding the defects causes the compression necessary to maintain a 10^{-3} cfm leakage to be increased to 20%.

Figures 6 through 11 show the same relationships for three hardnesses of molded one-piece solid elastomer gaskets. Figures 6, 8, and 10 show results for the gasket that showed the best leakage sealing characteristics in each group. Figures 7, 9, and 11 show results for gaskets having poor leak sealing characteristics for each group tested. For the gaskets with good leak sealing characteristics, compressions of about 10% are required to reduce leakage to 10^{-4} cfm when tests are run without defects. Addition of artificial defects requires compressions of up to 30% to reduce leakage to only 10^{-2} cfm. In some cases, the poorer sealing gaskets would not reduce leakage much beyond 10^{-2} cfm even at compressions of about 25%. When artificial defects were added to these tests leak rates dropped to 10^{-2} cfm and leveled out there at compressions greater than 30%. It can be seen from these figures that solid elastomer gaskets do not provide good seals around defects.

In addition to this, solid elastomer gaskets with large variations in individual thicknesses do not seal well. The gaskets tested for Figures 6, 8, and 10 had thicknesses varying up to 0.035 in. while those for Figures 7, 9, and 11 had thickness variations up to 0.050 in. Figures 12, 13, and 14 show the variations in thickness for the good and bad sealing gaskets in each hardness group. It can be seen that all the gaskets measured have some variation in thickness. However, the gaskets with relatively poor sealing characteristics were found to have large variations in thickness at or near the corners (marked by the vertical lines in the figures). This appears to be the most significant point in examining gasket for performance comparison.

Relaxation. A series of tests was run to examine the changes in compression pressure on gasket samples with time at a given compression. When a gasket sample is maintained at a given percent compression (35% in this series of tests) the sealing pressure it exerts relaxes with time. As mentioned above, this is measured by finding the amount of torque necessary to move each nut on the clamping devices. Figure 15 shows the results for the three hardnesses of molded gaskets studied. The gaskets relax most in the first day after clamping and then gradually reach a terminal point when equilibrium is established. Equilibrium pressures are between 26% and 60% original clamping pressures for the three hardnesses of gaskets. During the course of this test the 40 durometer gasket started deteriorating. Relaxation data for other gasket materials have been given previously.[1/]

Excessive Compression. During the course of the testing it was noted that the molded solid one-piece gaskets had a tendency to permanently deform, primarily by tearing, at compressions greater than 35%. Figures 16 through 20 show various stages of tearing under compression over a period of a few weeks. These photographs were taken through glass plates which were used to compress the samples. Figures 21 through 25 are photographs of a sample at compressions of 0, 15, 25, 35, and 40%. The surface of the gasket that would have been attached to the filter frame shears first. This can lead to severe problems in filter leakage in that (1) the tearing gasket was found to separate the plies or joints of a plywood filter frame (Figure 26), or (2) the gasket may tear in such a way that would permit leakage through it.

This point is significant because high compressions are required for molded solid rubber gaskets to seal around defects. High compressions required for sealing with these particular gaskets are not compatible with gasket integrity. Closed-cell neoprene gaskets without skin surface do not exhibit such problems at high compression nor do they require high compressions to seal around defects.

CONCLUSIONS

Testing HEPA filter gaskets on a full scale test facility simulating operating conditions has made it possible to study gasket sealing properties and to reach some conclusions regarding their performance.

1/ Op. cit.

The first and perhaps most obvious conclusion is that gaskets with a skin surface are not suitable for HEPA filters in that they cannot seal adequately around defects in the mounting surface. It is doubtful that a softer (<35 durometer) molded gasket with a skin surface would be any better than those tested. Gaskets without a skin surface can conform more readily to irregularities in mounting surfaces and thus create an adequate seal.

Because of the problem of sealing around defects for gaskets with skin surfaces, compressions of 40% and greater are required to approach minimal leak sealing. This leads to another significant problem with solid molded gaskets, that of gasket failure. Structural integrity of solid gaskets is lost at higher compressions. This also results in frame damage and potential massive gasket leaks. Neither of these situations is tolerable because they detract appreciably from the high efficiency concept of the filter medium. The problem of solid gasket integrity is attributed to the material displacement that takes place on compression of solid elastomeric material. Cellular gaskets do not demonstrate this difficulty since they do not require high compression for adequate sealing and their compression characteristics are different.

Difficulties in producing adequate sealing are also encountered when the gasket material relaxes. It has been shown that gasket pressure at a given compression decreases with time. To compensate for this, a provision must be made to retighten the filter about a week after the original installation.

It is imperative that during the manufacture of solid molded gaskets, rigid dimensional tolerances be maintained. During the course of the test, it was found that large variations in gasket thickness had adverse effects on leakage characteristics of the gasket. This effect was most pronounced when the large thickness variations were at or near the corners of the gasket. Thus, to avoid this part of the problem, gaskets should be finished to ± 0.01 in. in thickness. A tolerance this strict is necessary to provide adequate seals for variations in mounting surfaces and techniques of filter installation.

Over the narrow range of hardnesses of molded solid gaskets tested, no outstanding advantage was found for any given hardness. All molded gaskets had the same general characteristics when sealing around defects but the gaskets of 40 durometer demonstrated greater shearing characteristics at high compression.

RECOMMENDATIONS

Based on the tests reported previously and in this paper concerning HEPA filter gaskets, the following recommendations are made for consideration in the development of specifications for such gaskets and for their installation:

1. Gaskets should be made of a closed-cellular material.

2. Gasket shape should be rectangular, width 3/4 in. and thickness 1/4 in. or 3/8 in. All dimensions should be ± 0.01 in.

3. Joints, if any, should be firmly cemented with dovetail type joints.

4. Gaskets should be compressed at least 20% to obtain adequate sealing.

5. Filters should be retightened about a week after installation to compensate for relaxation.

6. If solid elastomer gaskets must be used, the filter frame should be made of a material other than plywood, and care should be taken that the gasket be compressed no more than 40%.

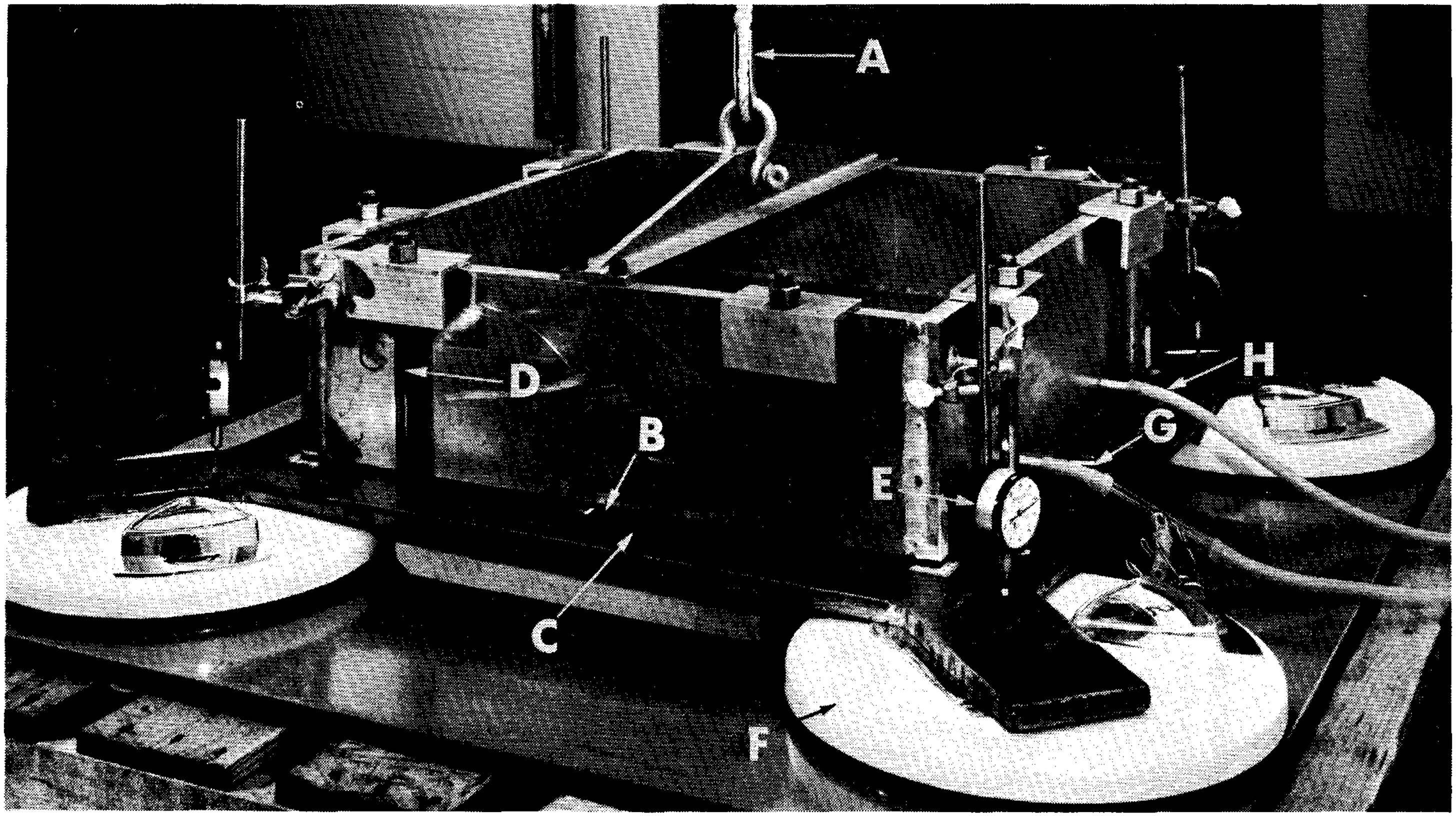

Figure 1 Aluminum Test Frame

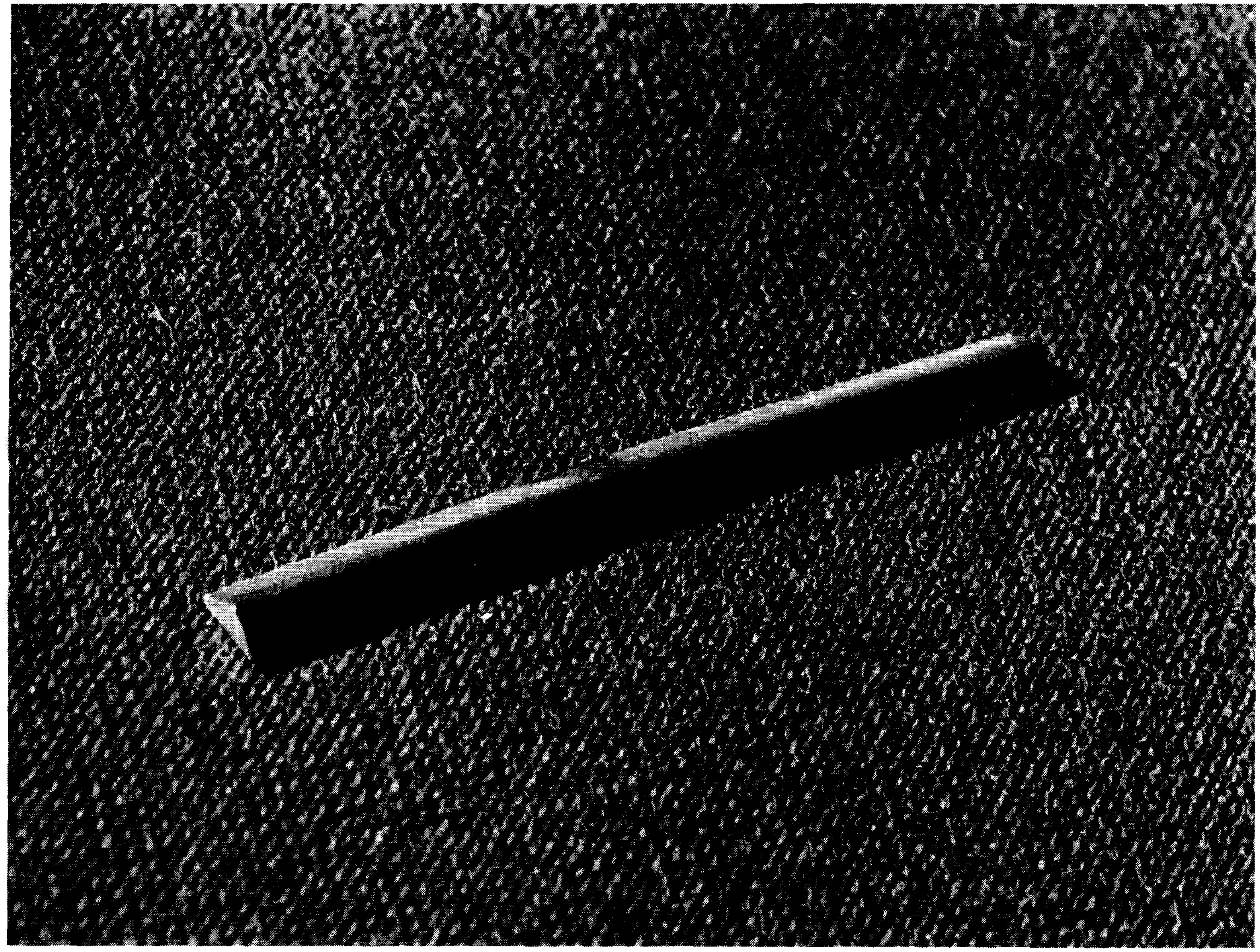

Figure 2 Artificial Defect

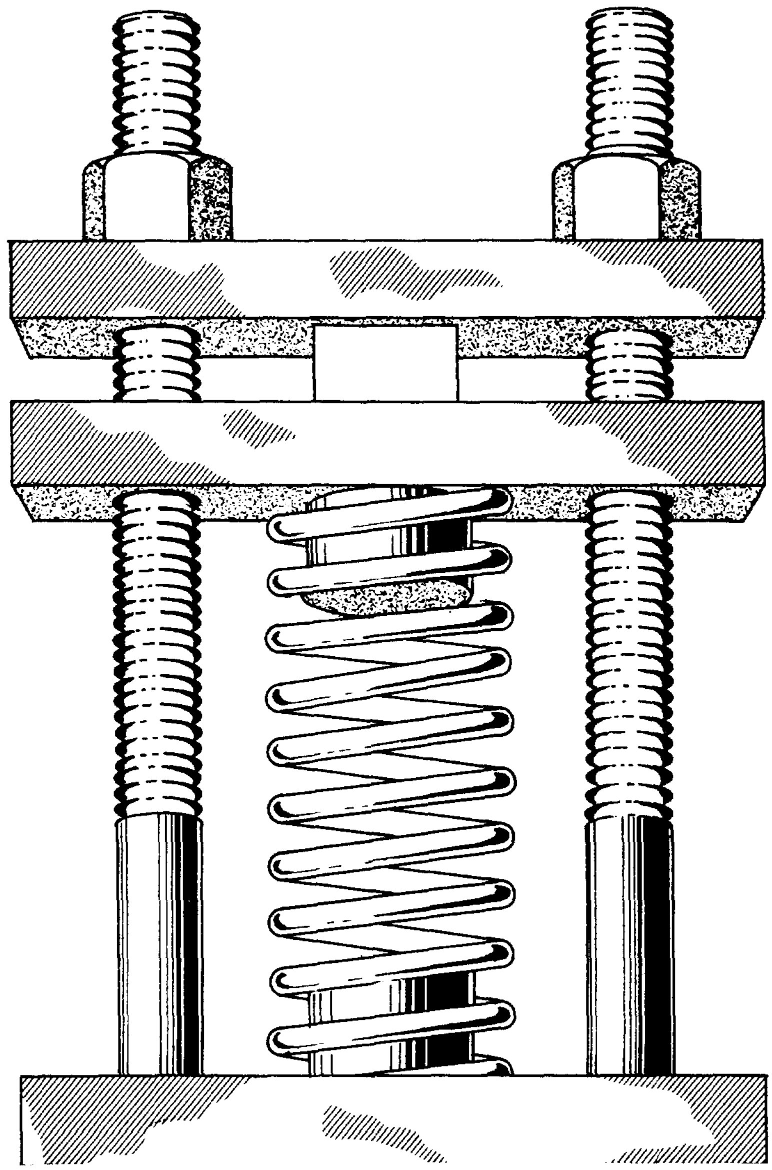

Figure 3. Compression Set Device

AEC-RL RICHLAND, WASH.

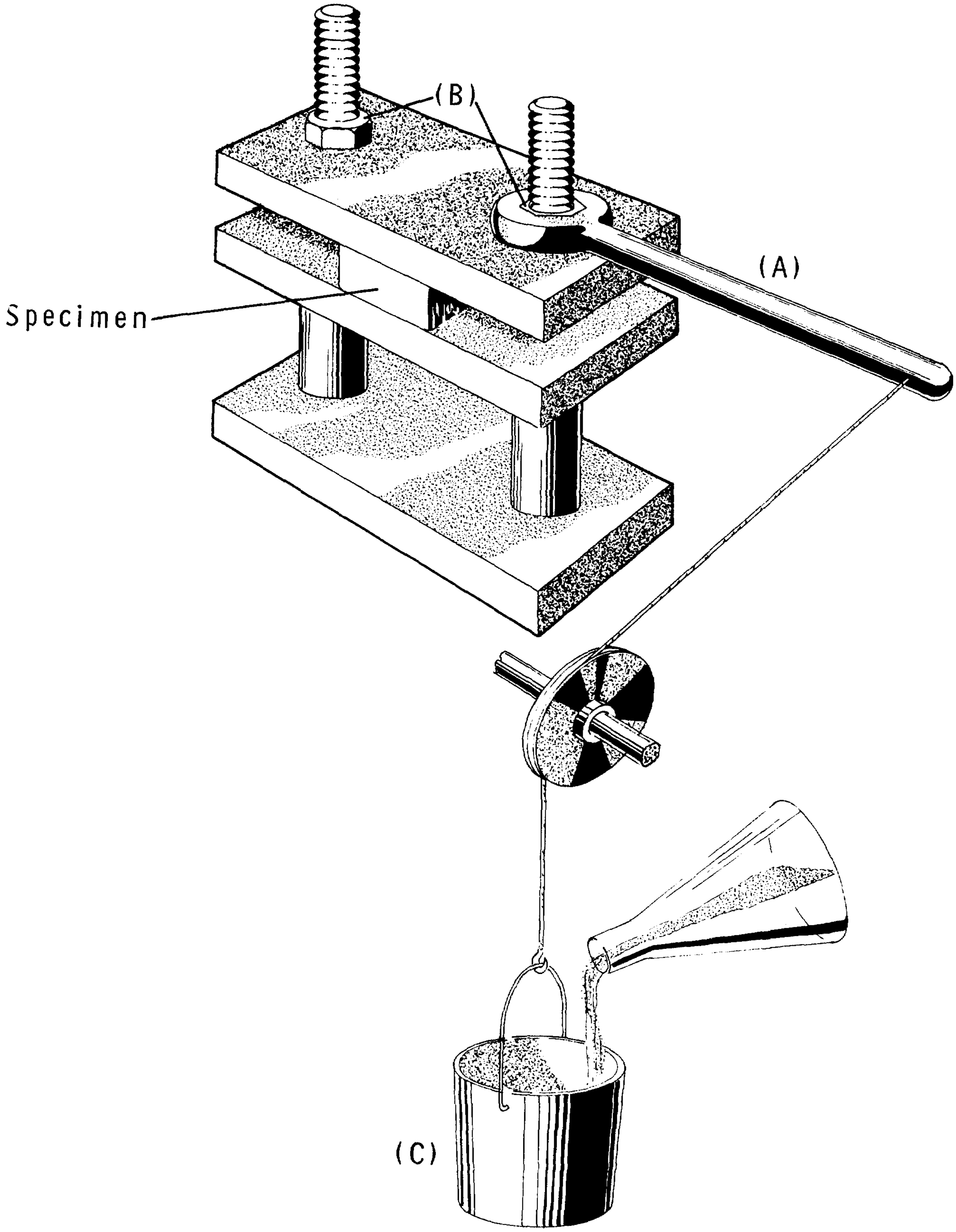

Figure 4. Compression Pressure Measurement

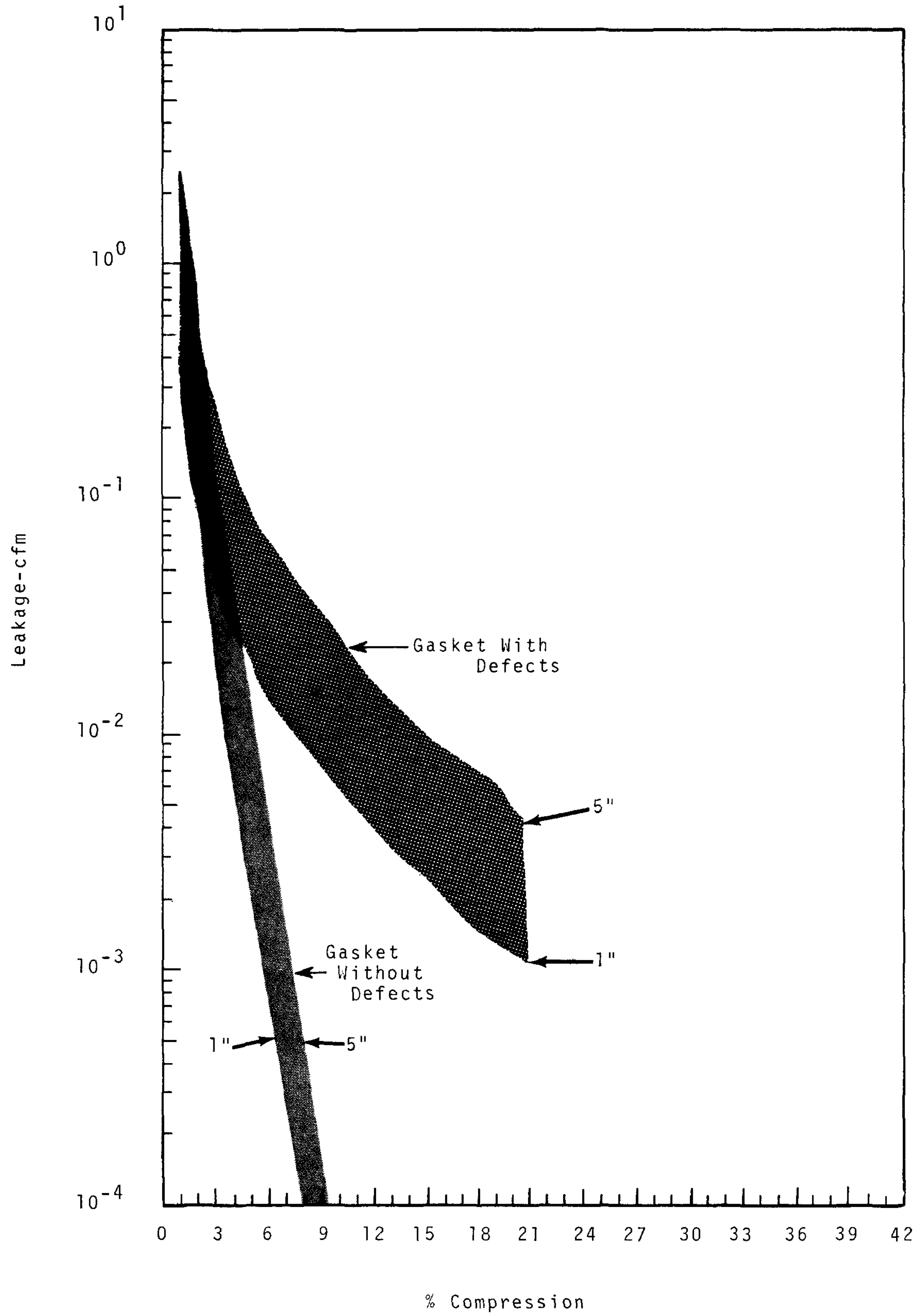

FIGURE 5. Leakage - Closed Cell Neoprene Gasket

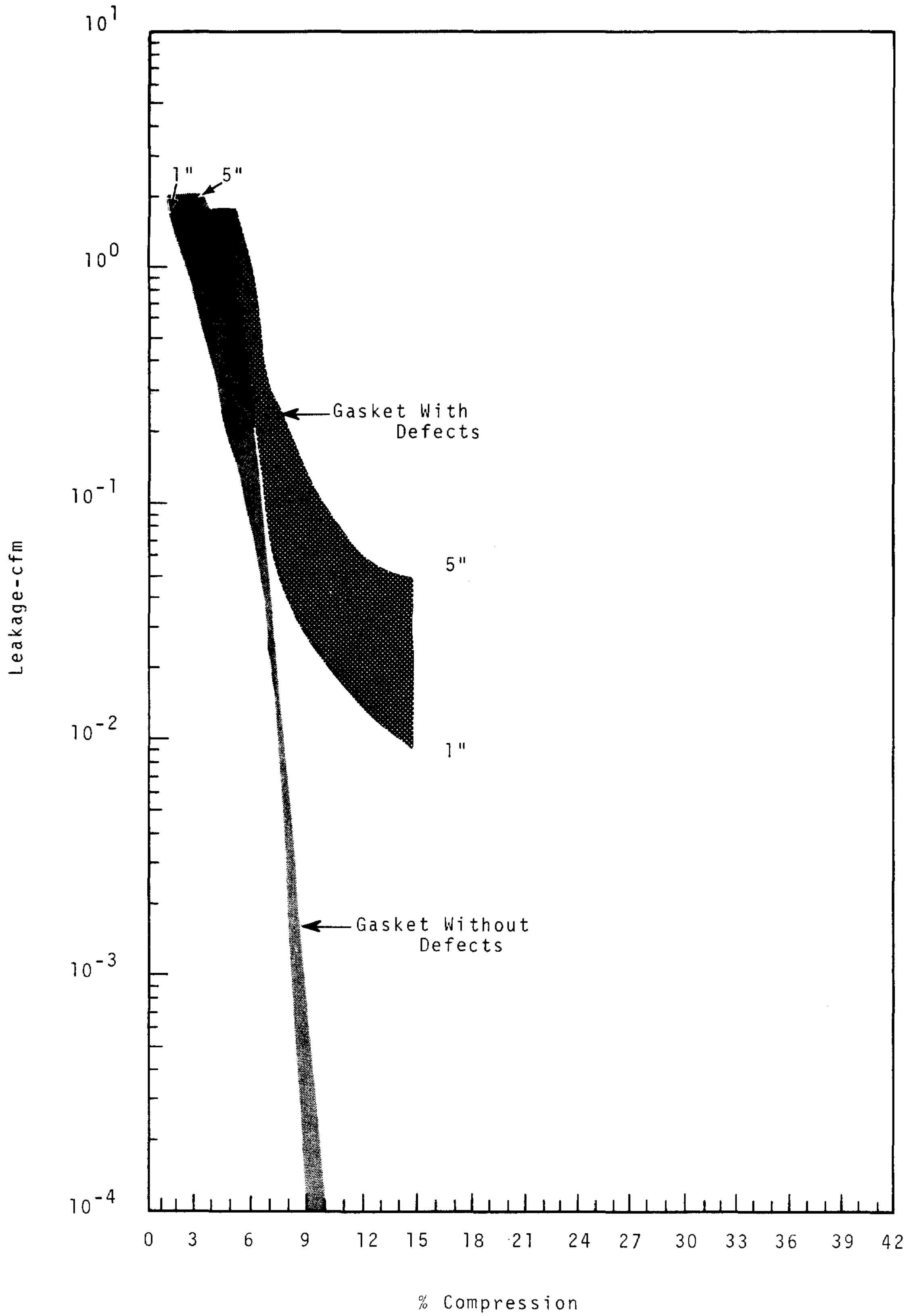

FIGURE 6. Leakage 50 Durometer Molded Gasket

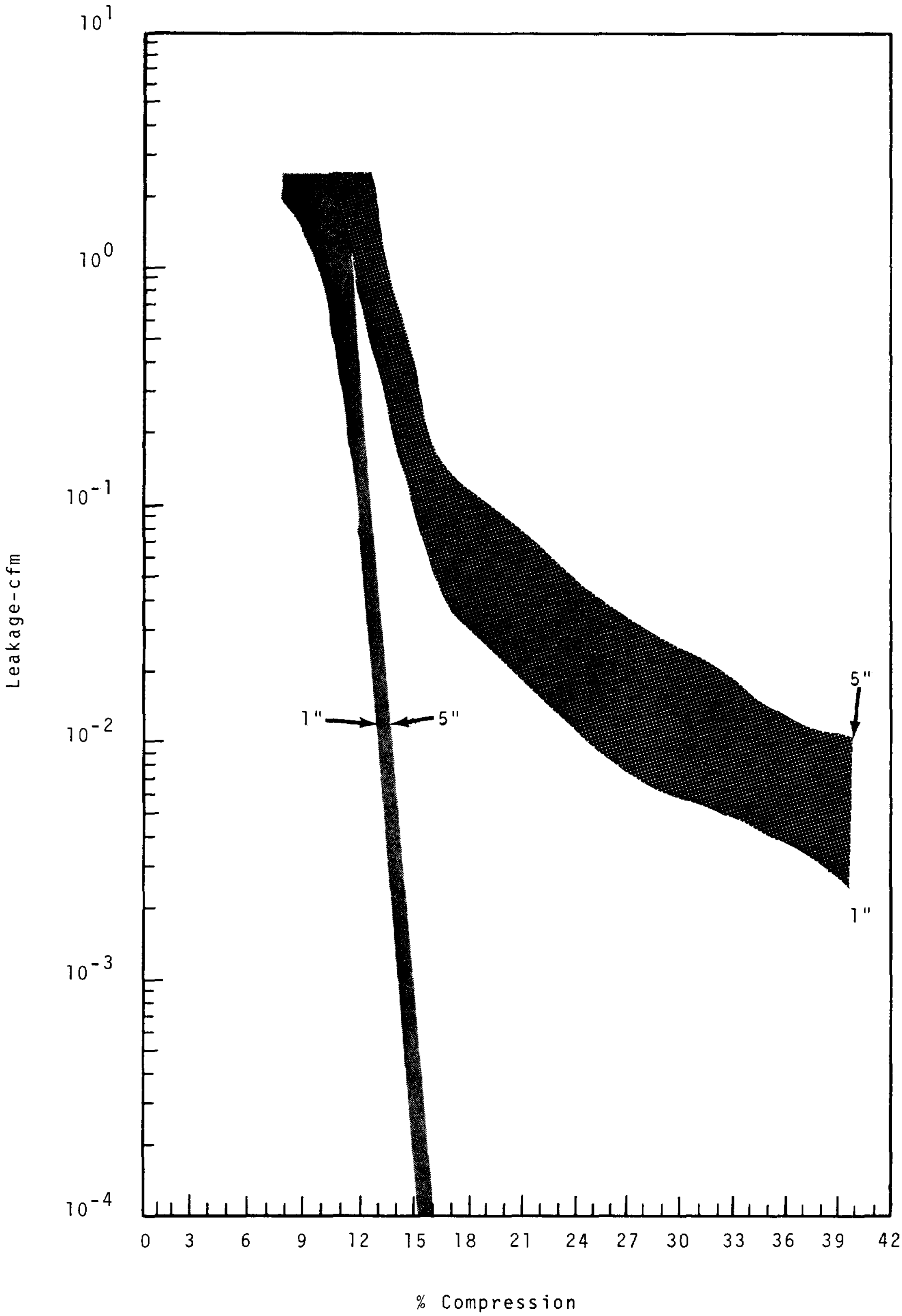

FIGURE 7. Leakage 50 Durometer Molded Gasket

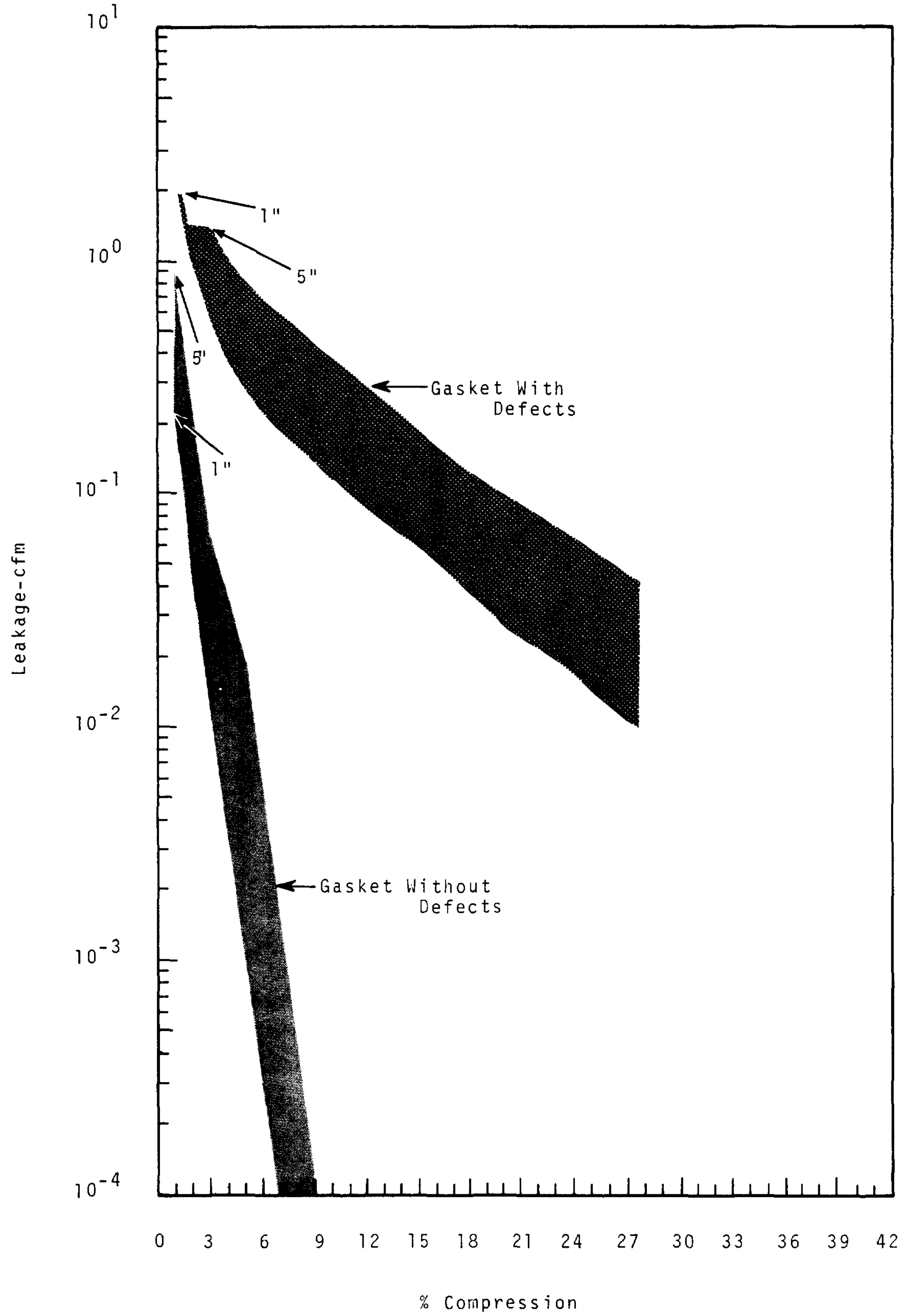

FIGURE 8. Leakage 40 Durometer Molded Gasket

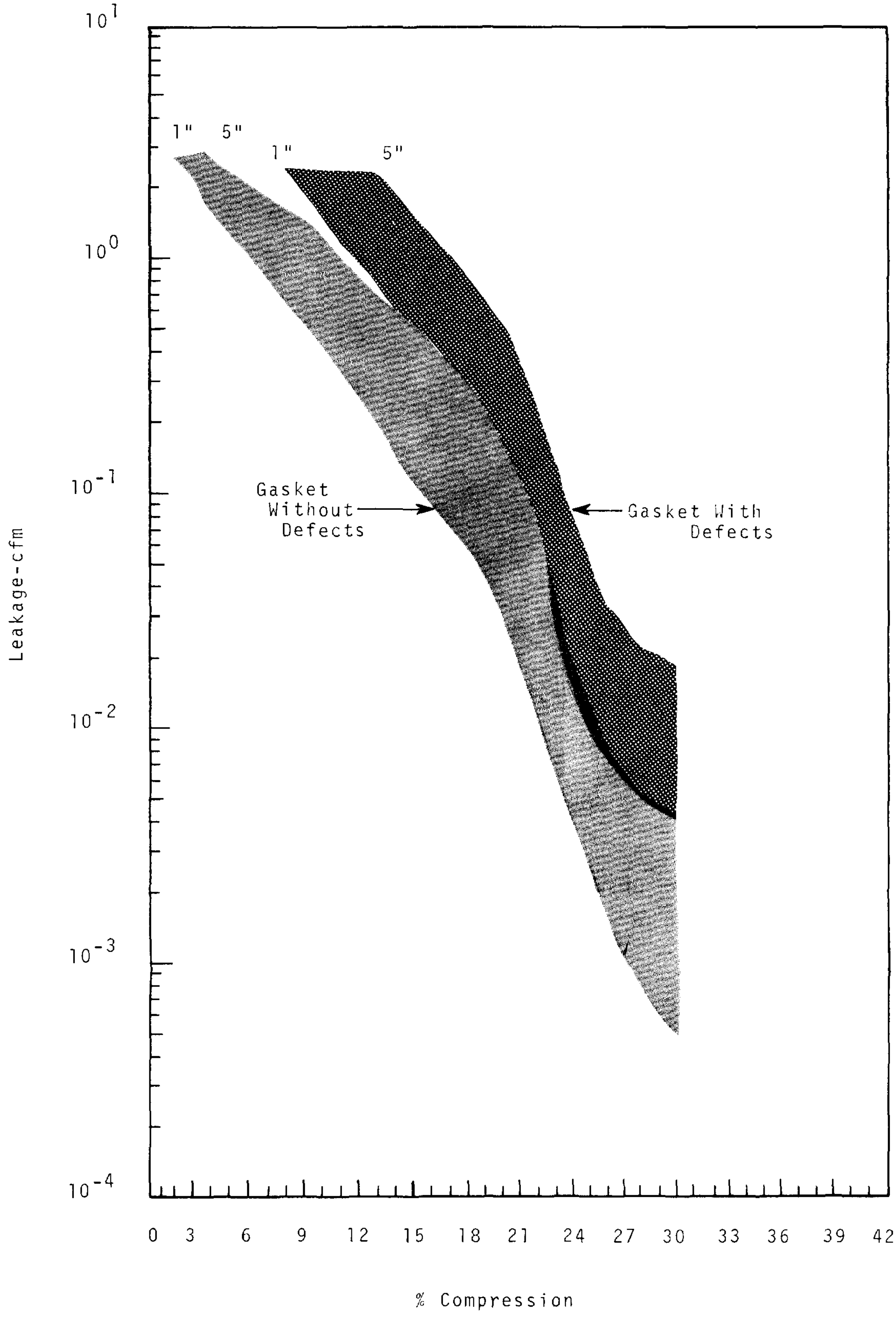

FIGURE 9. Leakage 40 Durometer Molded Gasket

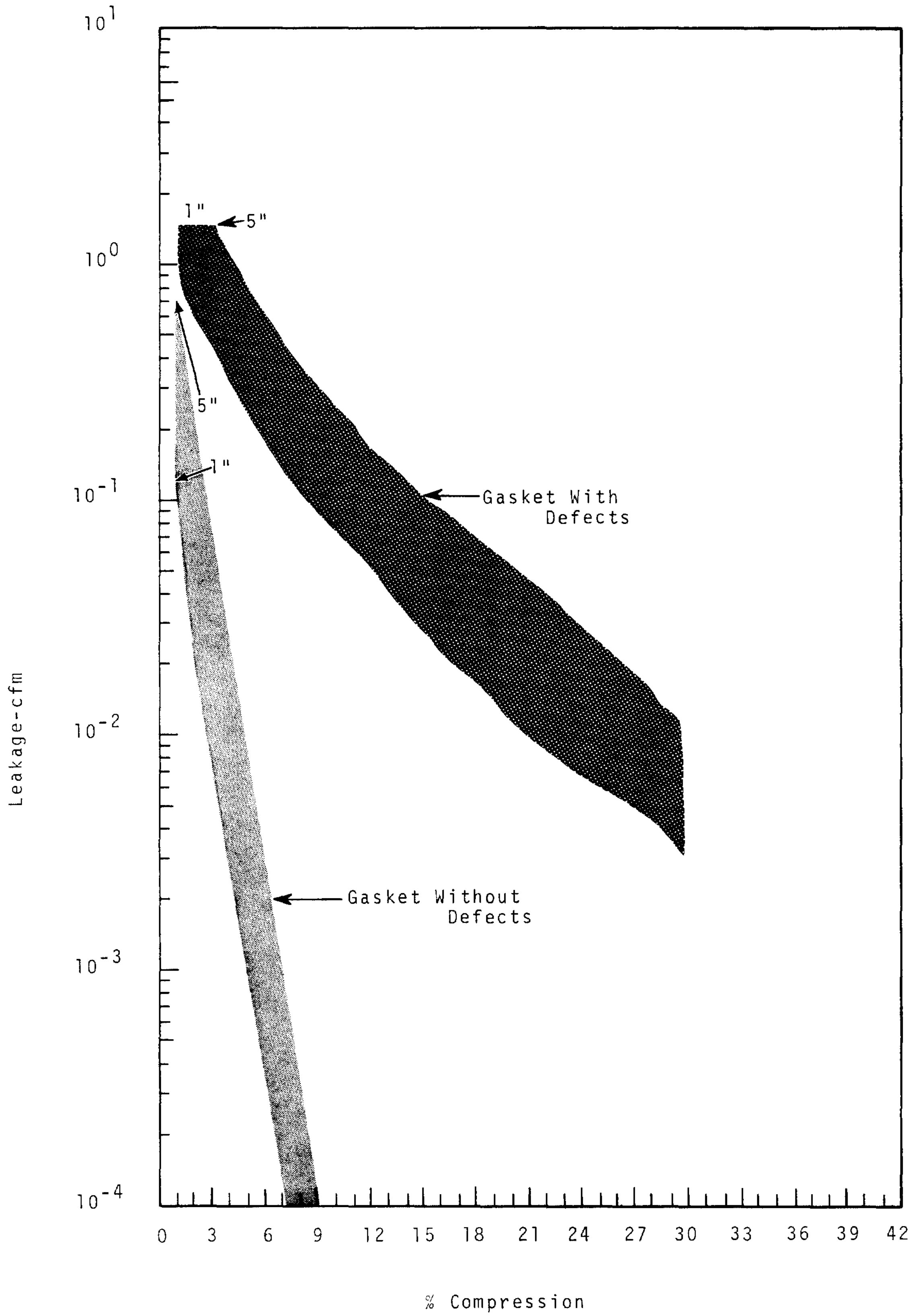

FIGURE 10. Leakage 35 Durometer Molded Gasket

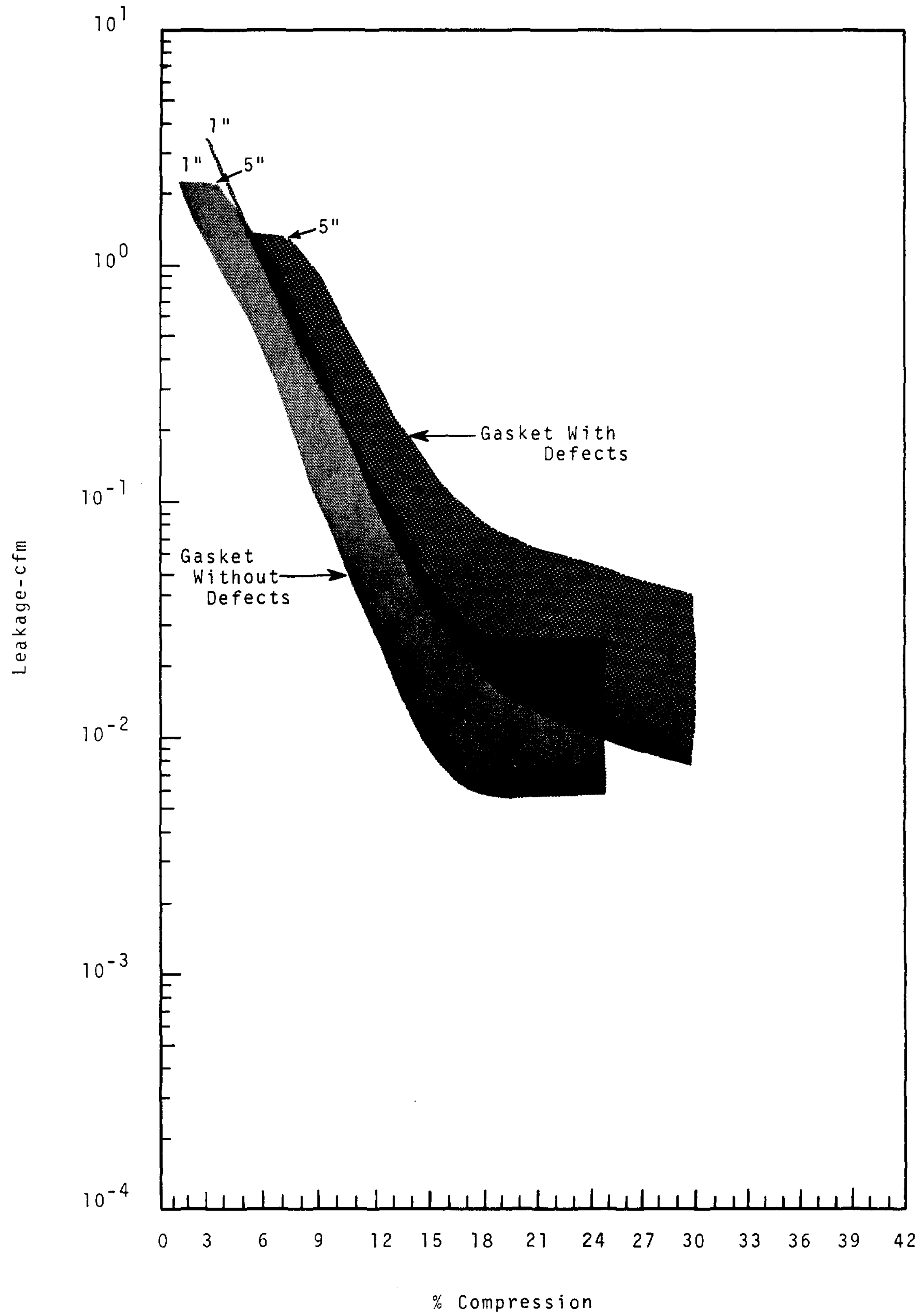

FIGURE 11. Leakage 35 Durometer Molded Gasket

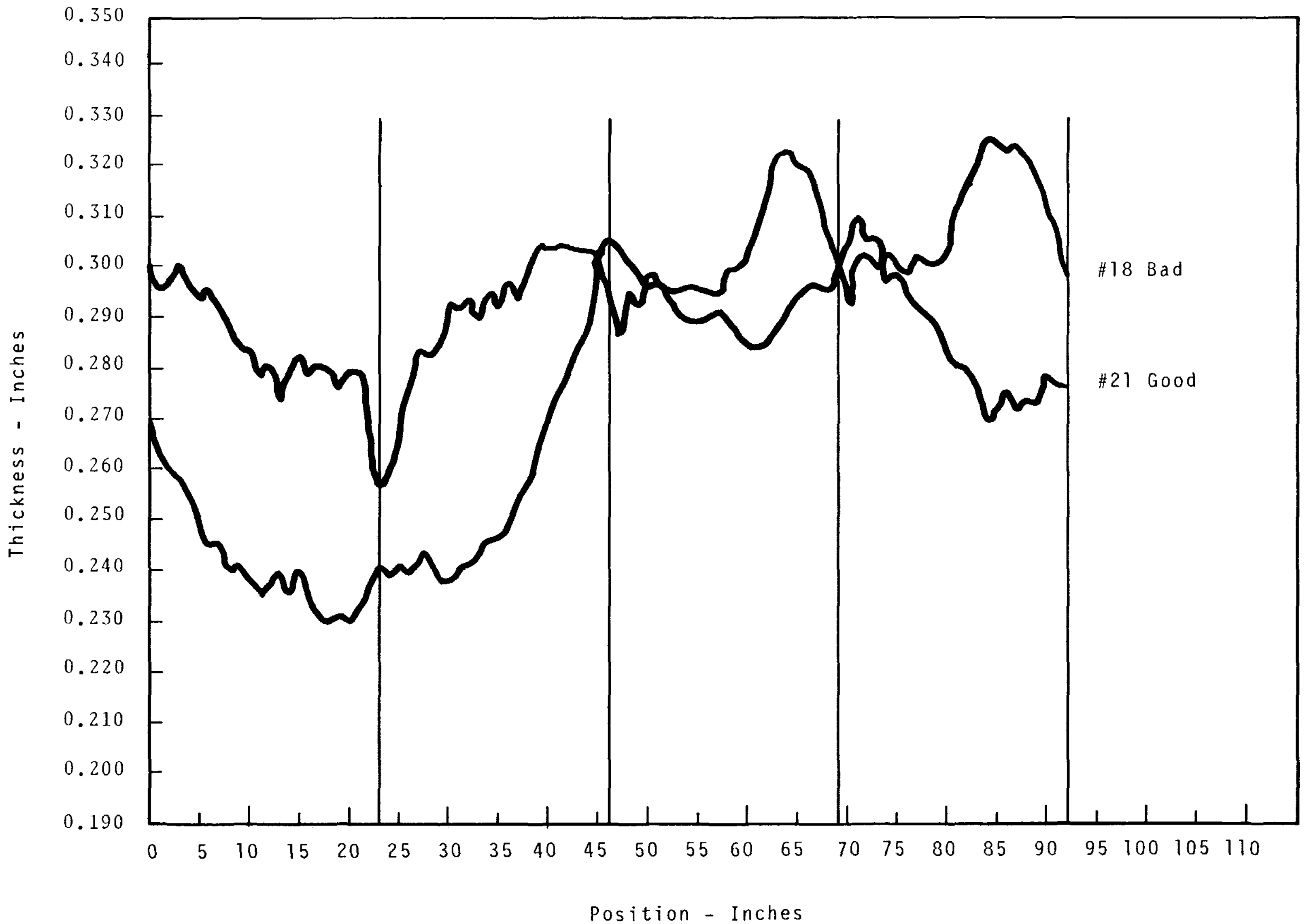

FIGURE 12. Thickness Variations 35 Durometer Molded Gaskets

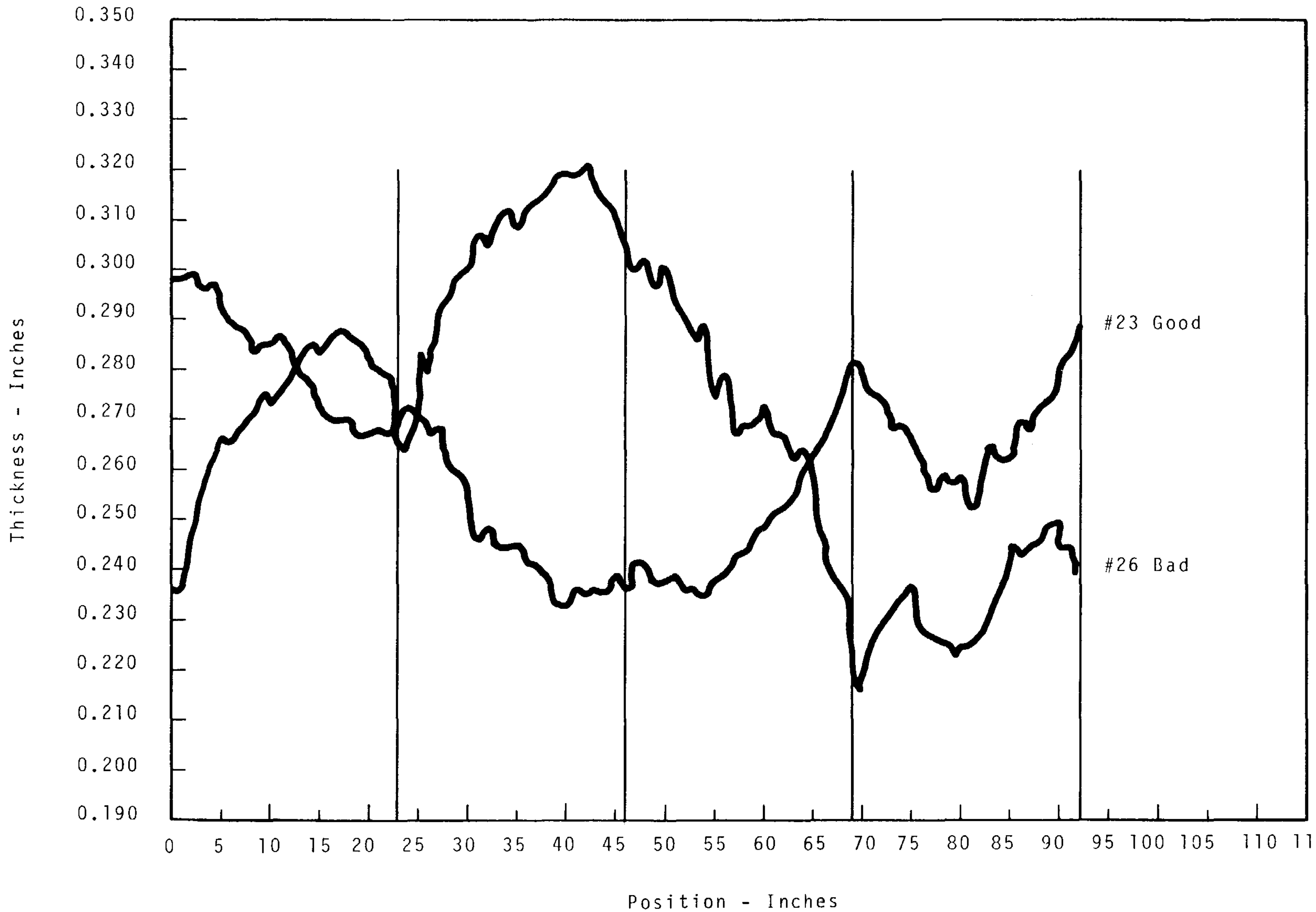

FIGURE 13. Thickness Variations 40 Durometer Molded Gaskets

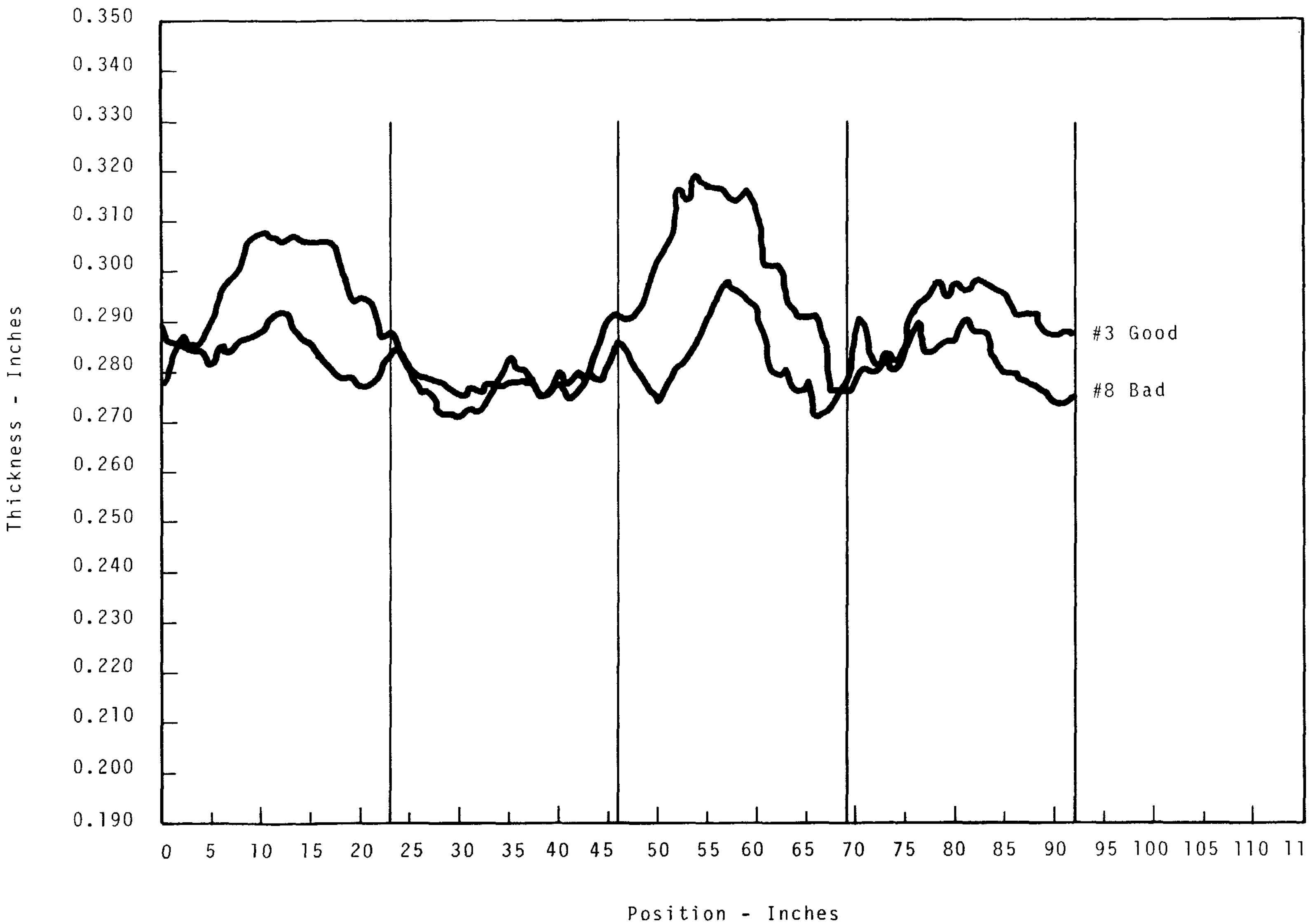

FIGURE 14. Thickness Variations 50 Durometer Molded Gaskets

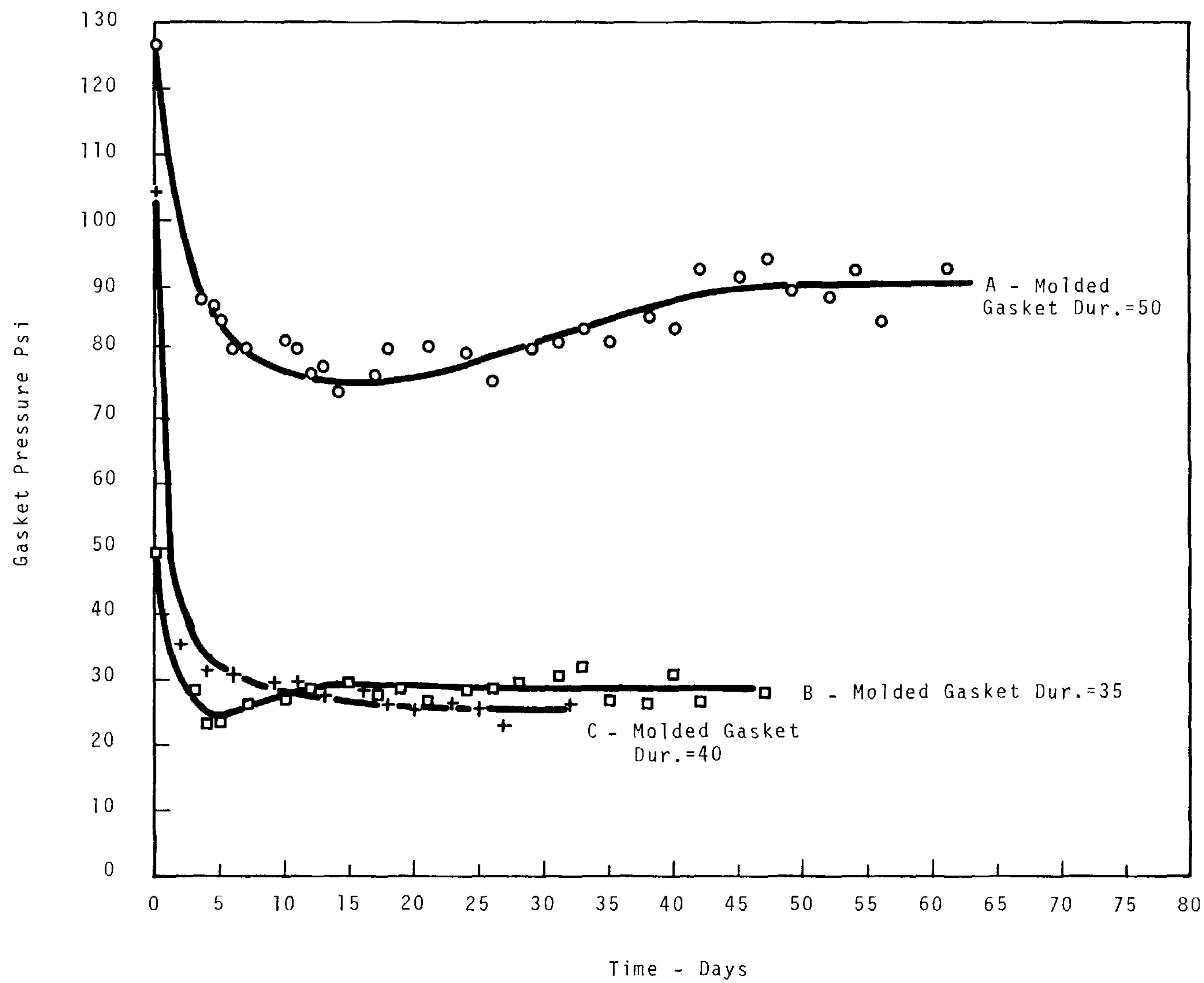

FIGURE 15 *Static Loading*

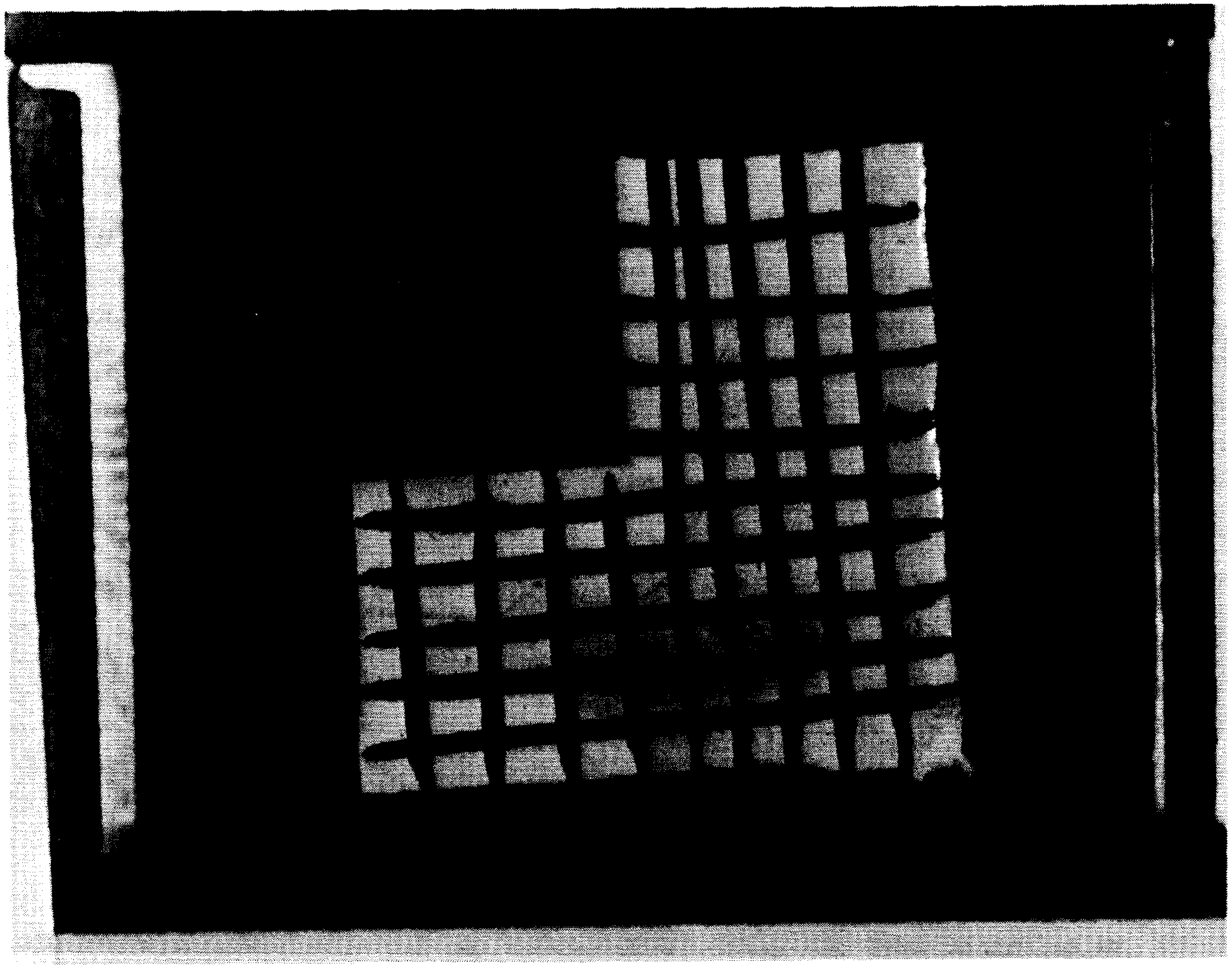

Figure 16 40 Durometer Gasket Section, No Compression

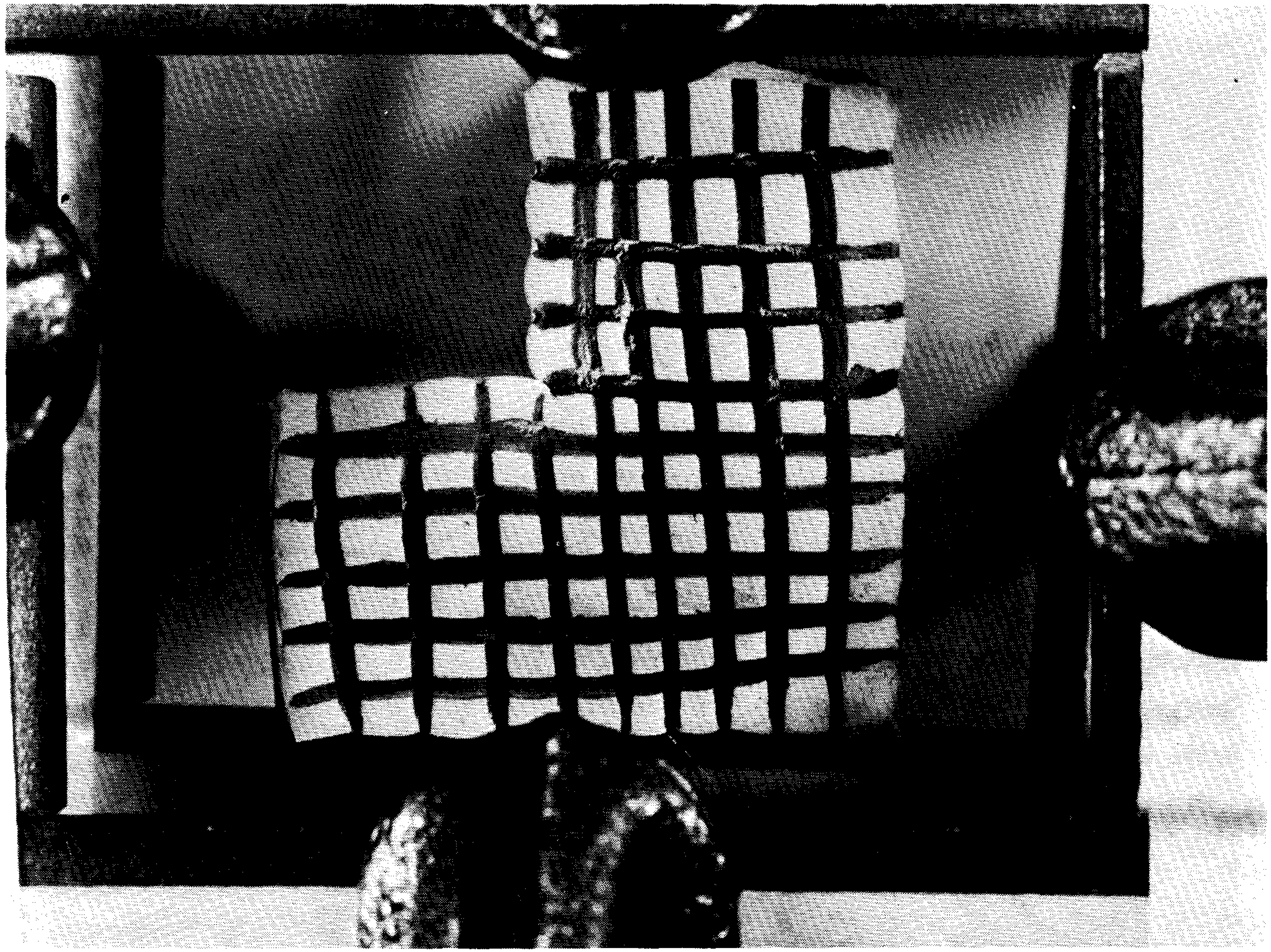

Figure 17 40 Durometer Gasket Section, 15% Compression

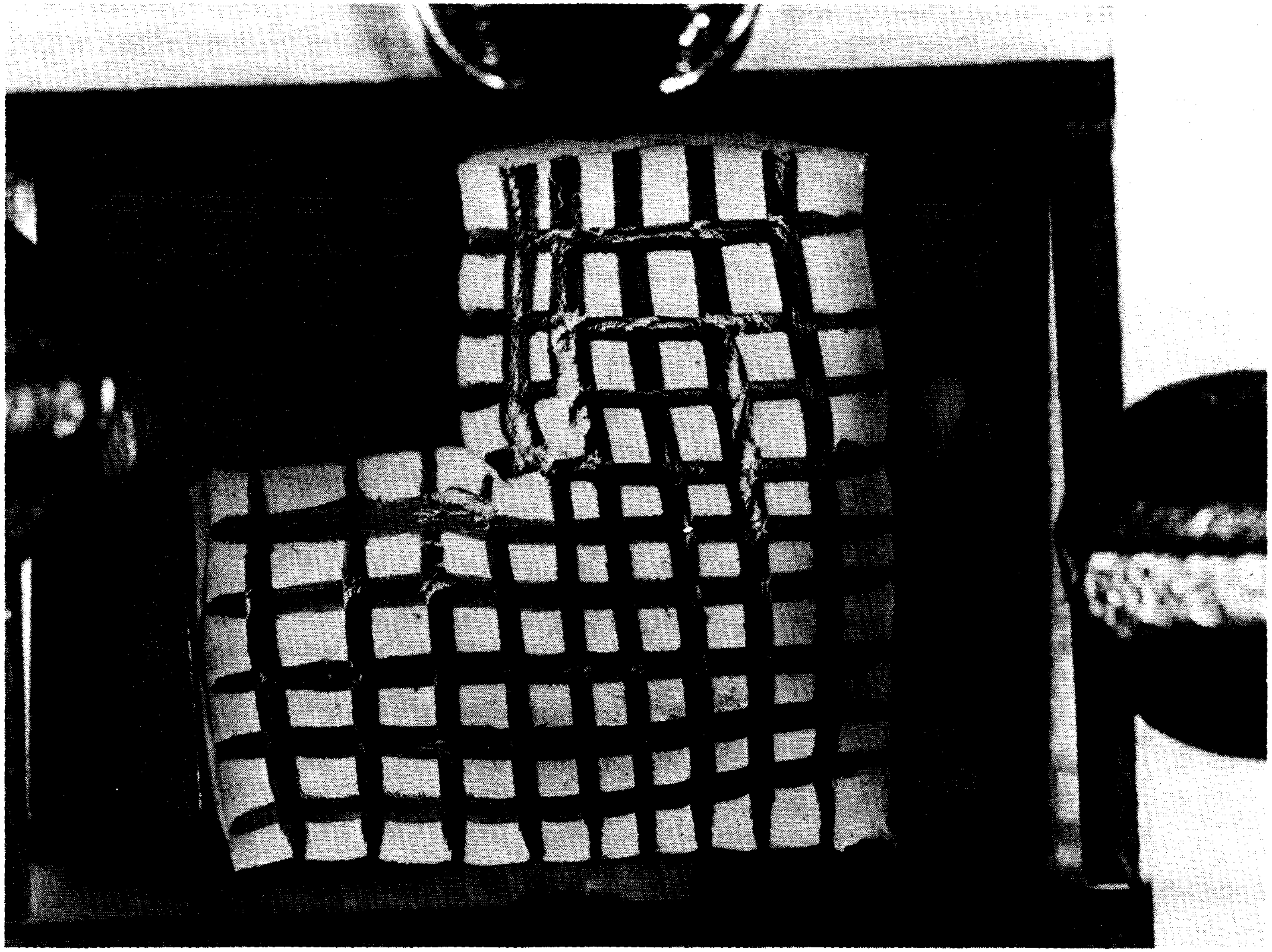

Figure 18 40 Durometer Gasket Section, 25% Compression

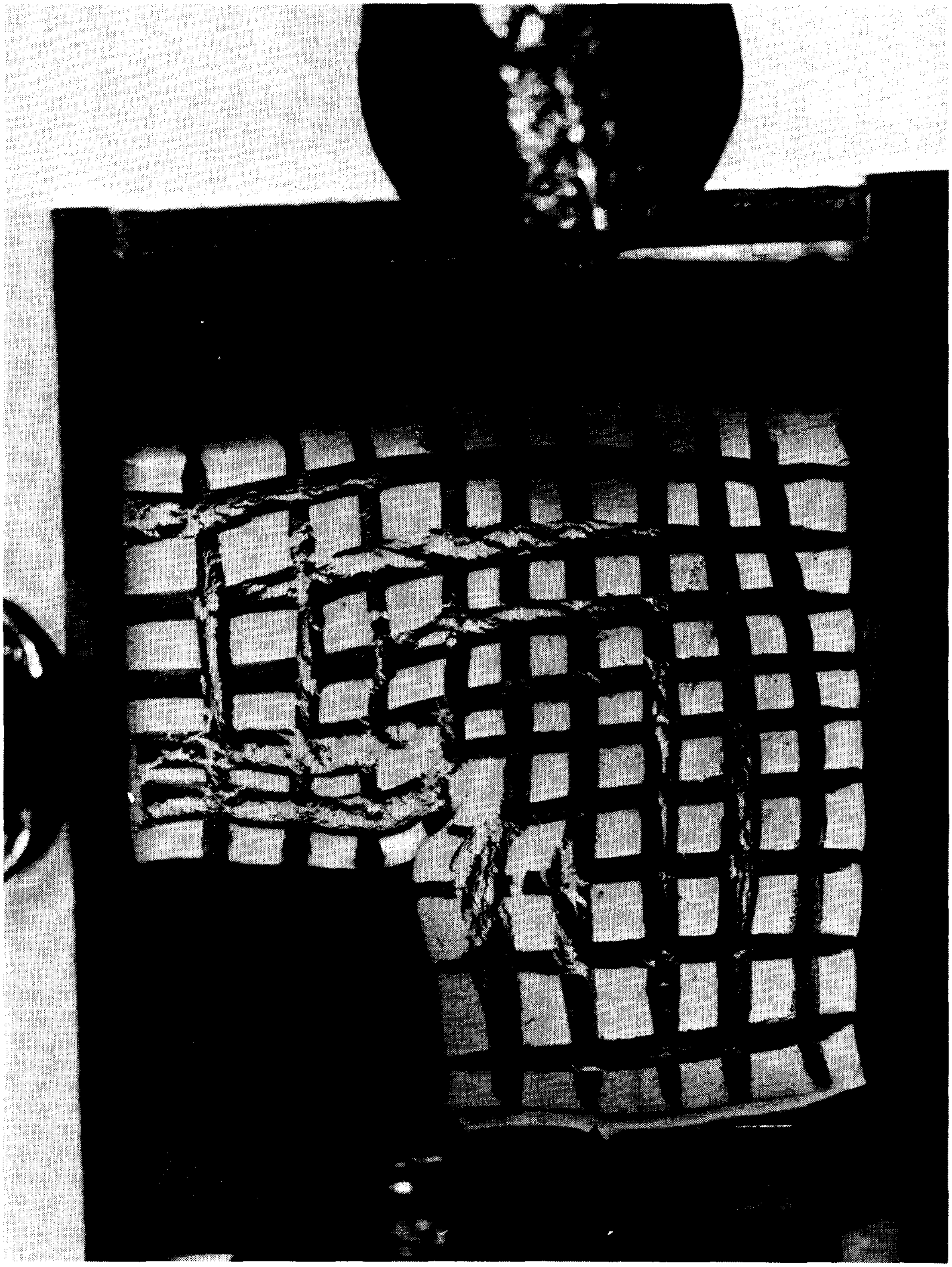

Figure 19 40 Durometer Gasket Section, 35% Compression

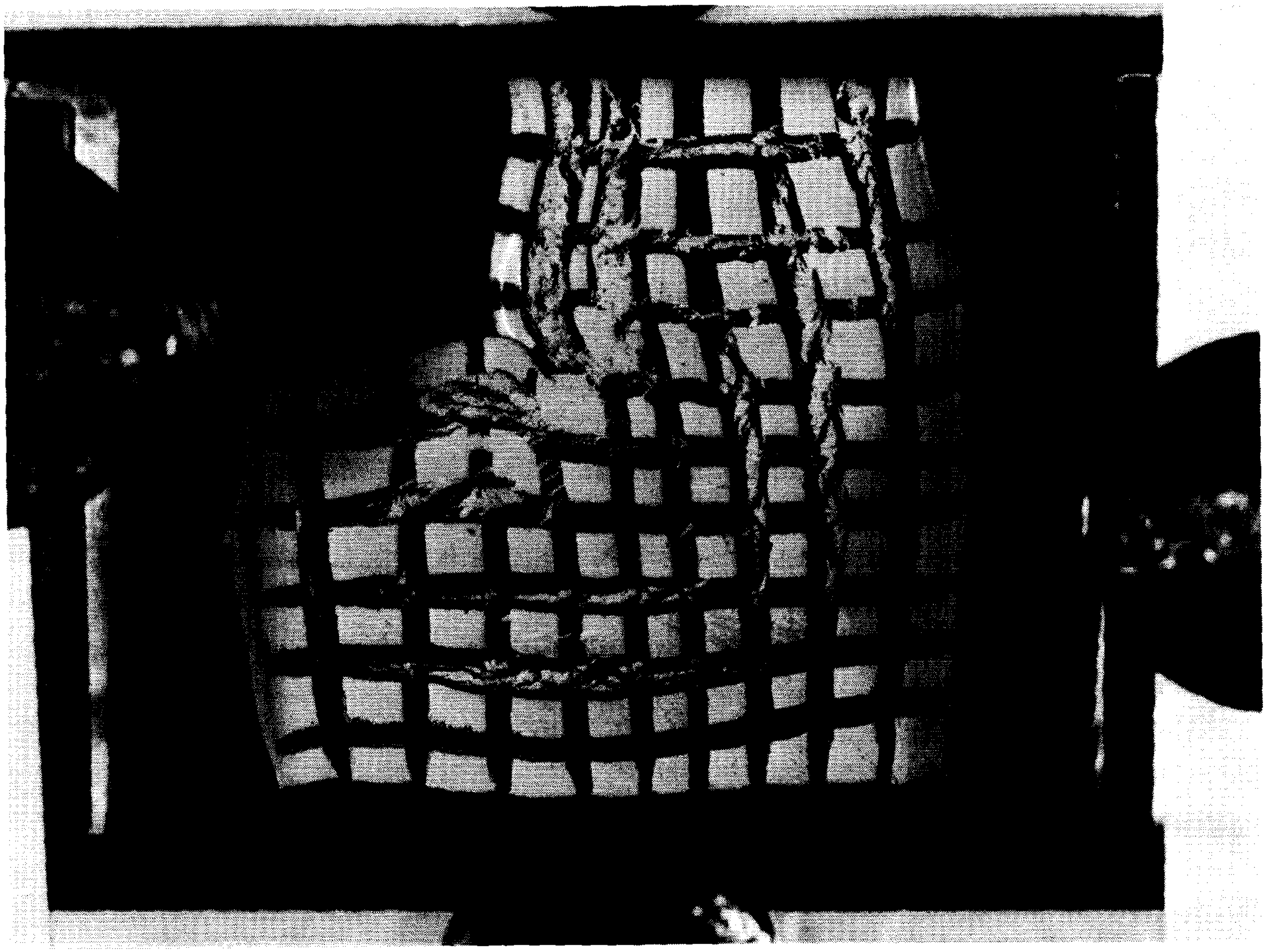

Figure 20   40 Durometer Gasket Section, 40% Compression

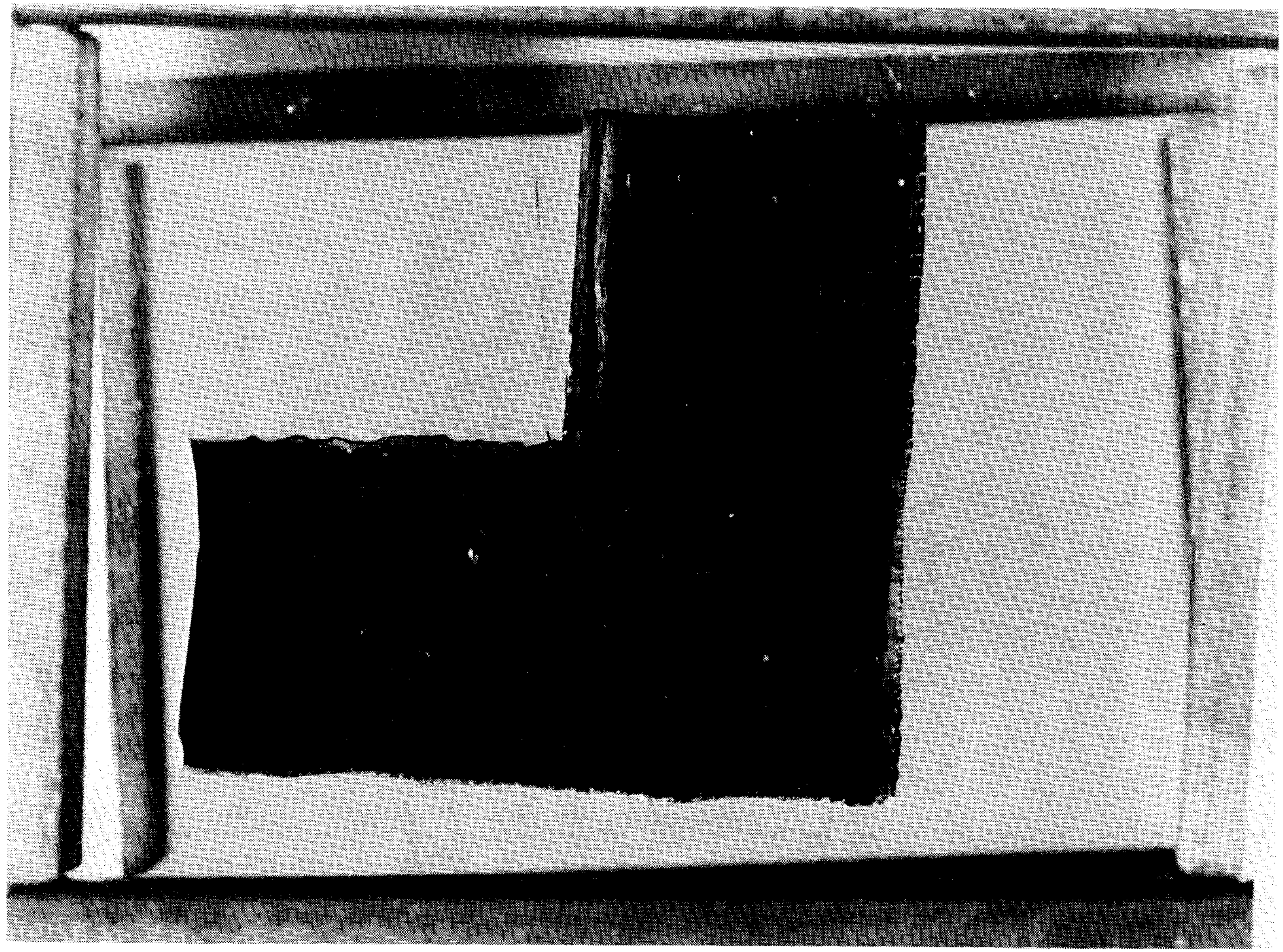

Figure 21 40 Durometer Gasket Section, No Compression

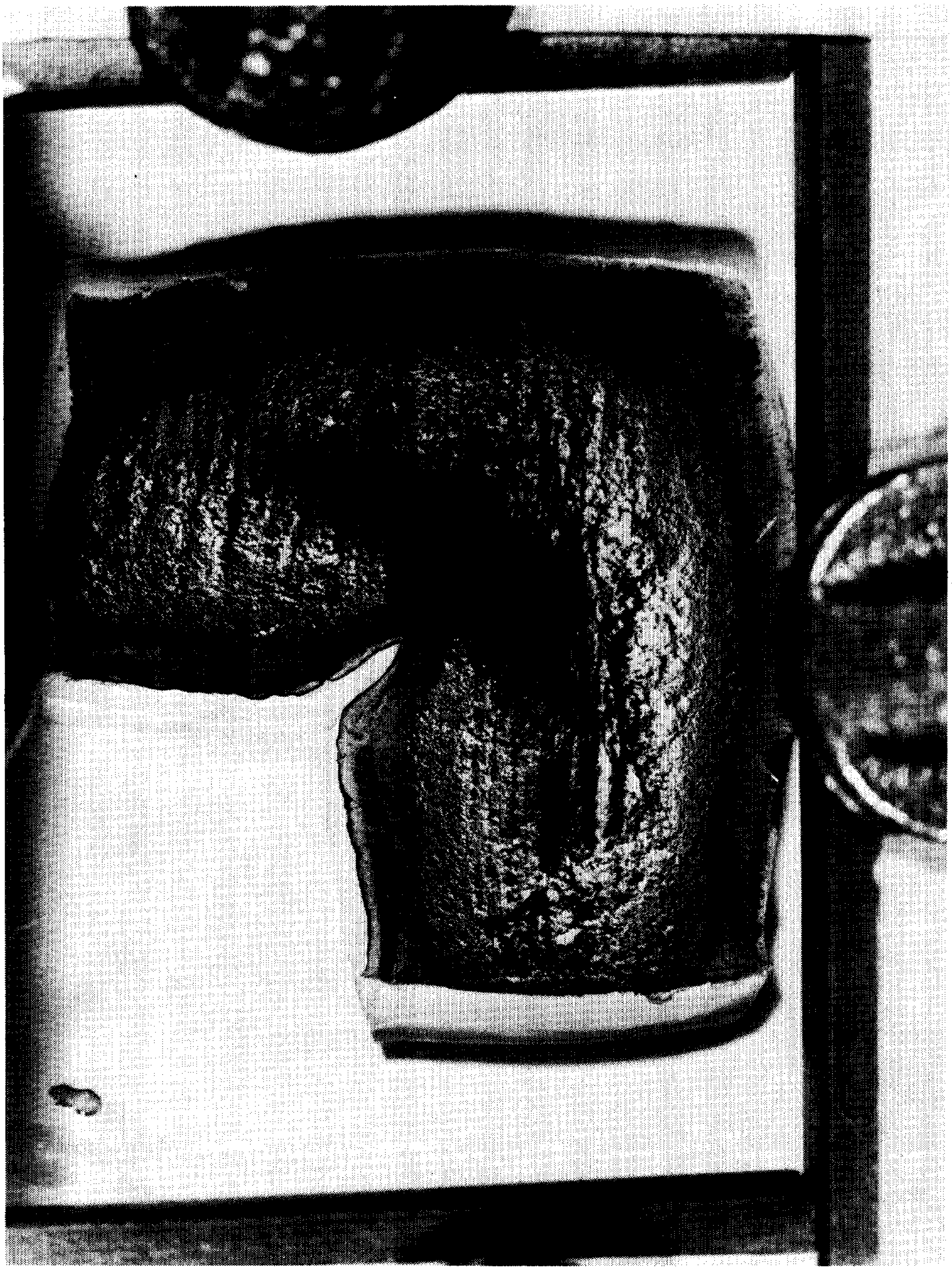

Figure 22 40 Durometer Gasket Section, 35% Compression, 1 Day

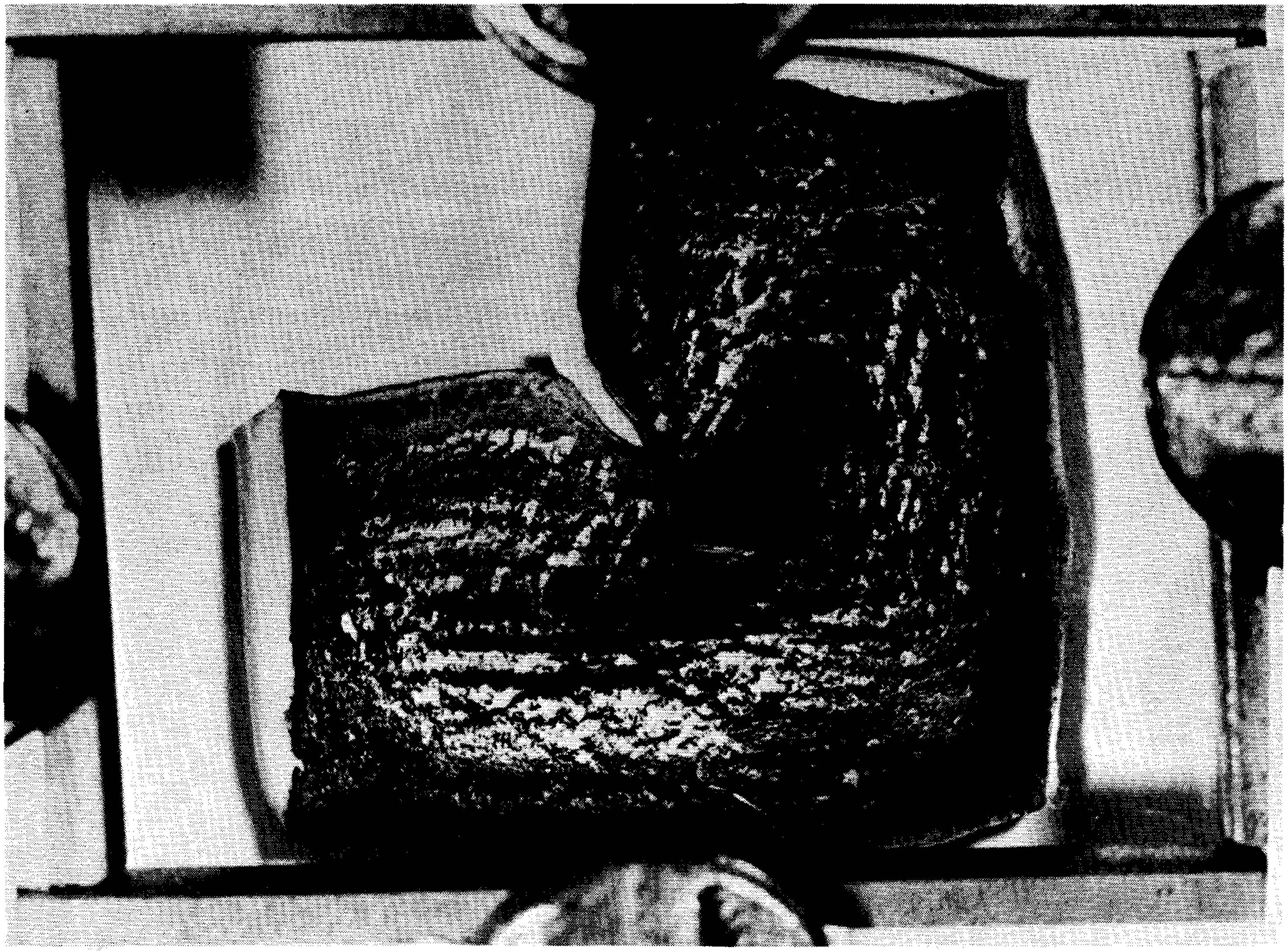

Figure 23 40 Durometer Gasket Section, 35% Compression, 5 Days

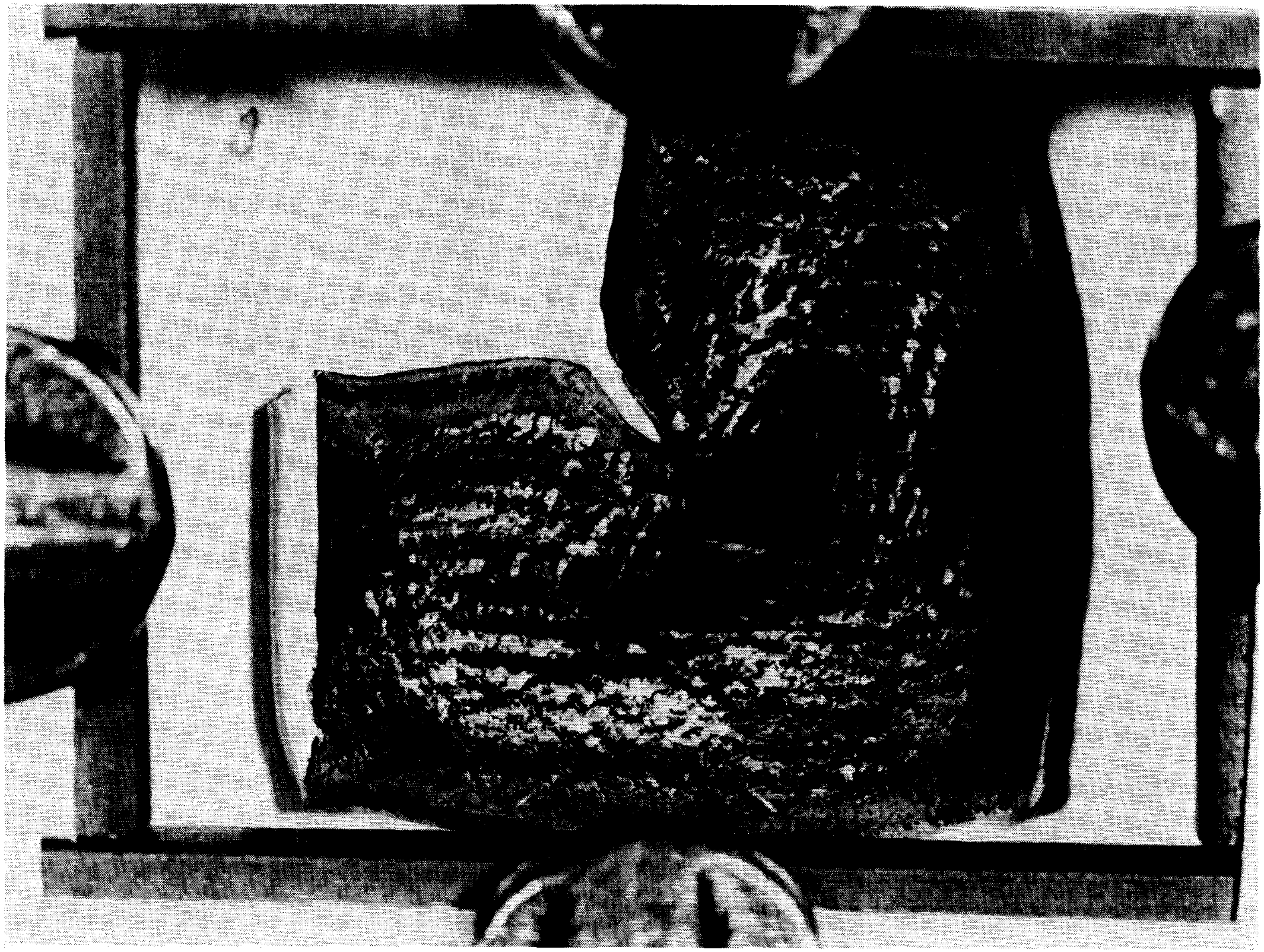

Figure 24 40 Durometer Gasket Section, 35% Compression, 15 Days

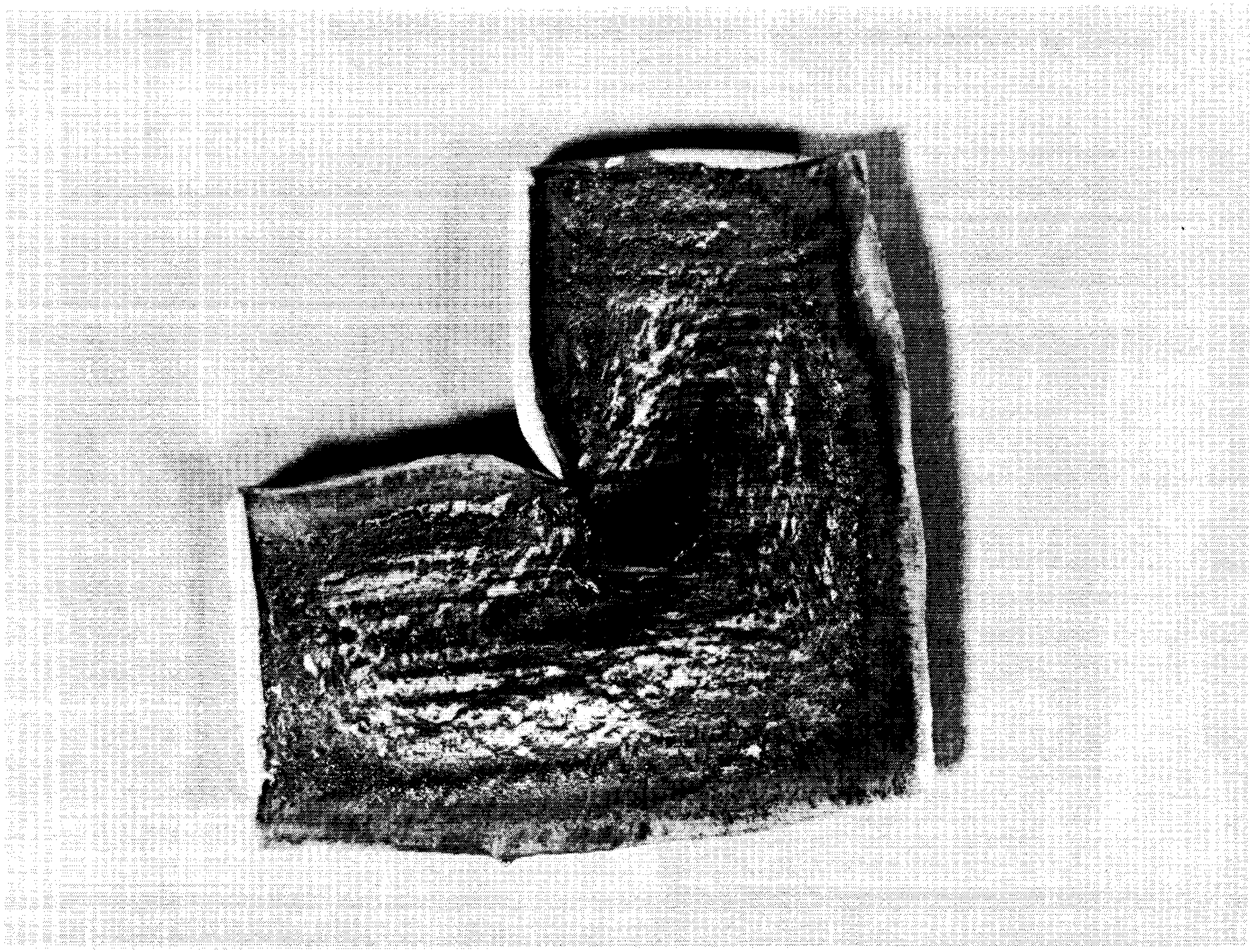

Figure 25 40 Durometer Gasket Section, 35% Compression, After Release

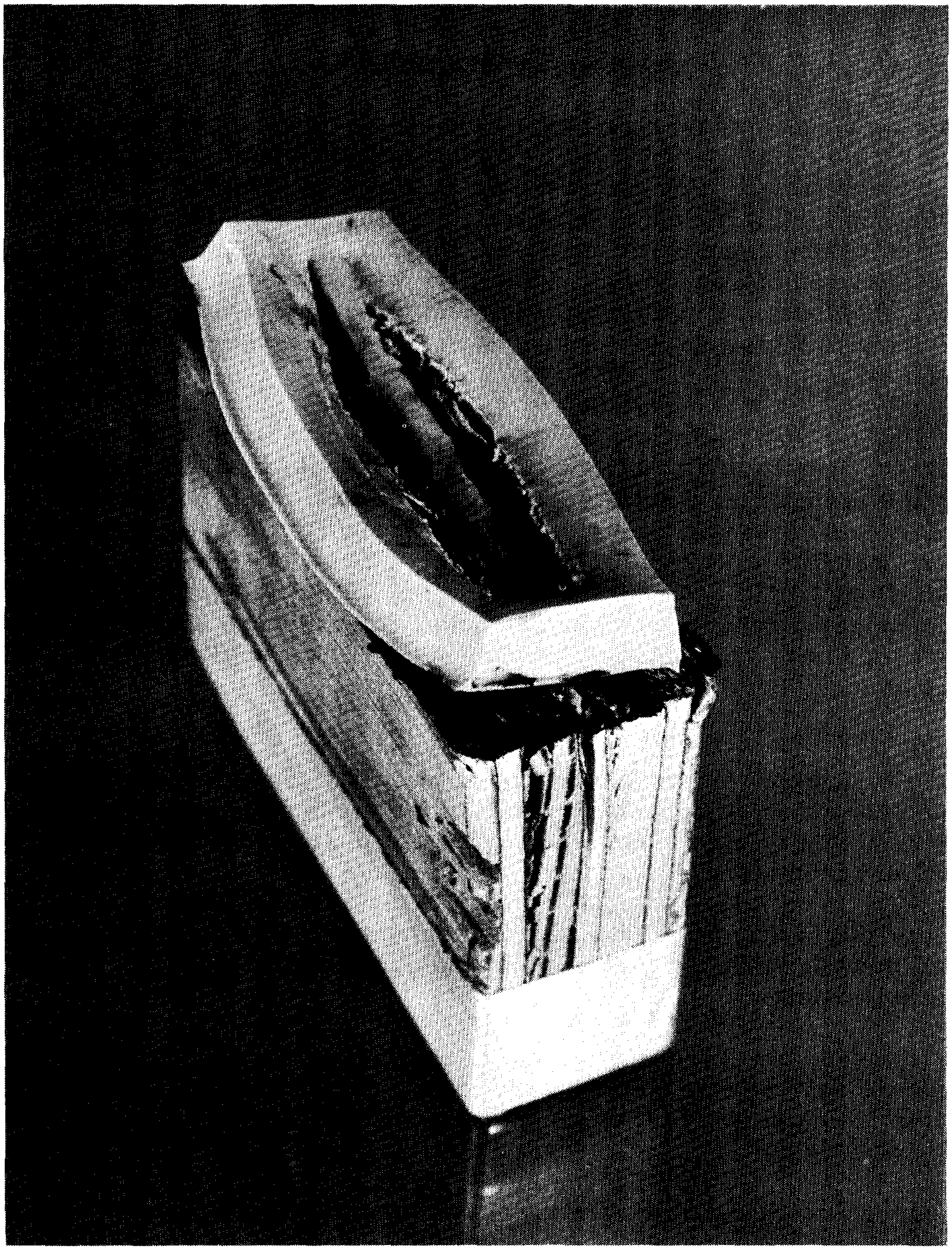

Figure 26 Plywood - 40 Durometer Gasket Section, After Compression to 60%

DISCUSSION

FICKS: My comment is addressed to Dr. First.

You discussed materials in the HEPA filter. We have a situation in Shippingport where we must store HEPA filters for a time. These filters come in a capsulated "poly" bag inside a fiber board box. Is there any work on the life of the filter with respect to the adhesive pulling away? Would it be better to take them out of these capsulated bags and leave them in the air of the storage warehouse? Is there any work being done on this?

FIRST: Not much work is going on on this topic. We will ask the audience if they have any information not yet released. There can be some deterioration of the filter due to mold formations, etc. when filters are sealed in a polyethylene bag at the time of manufacture and if it happens to be in an atmosphere which is quite moist. If, however, filters are packed and sealed in a polyethylene bag in a dry atmosphere, shelf life should be improved. Mr. Gilbert described filters* which were removed from storage after approximately ten years with a very high percentage of defects. However, filters manufactured today may be much better in this regard.

BURCHSTED: There will be a paper tomorrow by J. C. Little in which he will report on damage to filters taken out of storage where there has been no control over temperature and humidity during storage.* I also wanted to comment on the gasket study. The conclusion put forward was that gaskets should be compressed at least 20 per cent. Field experience puts it closer to 80 per cent to get a reliable seal. With the deficiencies that you find with gaskets seating surfaces, the seating surface of the mounting fixture as well as the backing surface of the filter element itself, 80 per cent, we find, is a whole lot better.

SIMS: We recommended this merely as a minimum to ensure some adequate sealing. Of course, some of our tests were performed on very rigid tolerance equipment so that this is intended as a minimum.

However, some gaskets will deform under higher compression and consideration must be given to that before specifying maximum.

BURCHSTED: I mention this because I didn't want someone to feel that 20 per cent was adequate. We've seen gaskets blow out between the filter and the mounting fixture sometimes.

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*International Symposium

SCHMIDT: Dr. First, I'd like to make a couple of comments on your review of development of filters and secondly, I should have jumped to George Sykes' defense yesterday when it was orally suggested that the operating sand filters were merely containers filled with sand with very little engineering data to aid in their development. I assure all of you here that this assumption is not true.

Both the large scale sand filters and the fiberglass filters were developed at Hanford. A great deal of engineering effort and operating data on a pilot plant scale were obtained prior to plant scale installation. Also, to put it into proper perspective for what we really feel at Hanford is that the fiberglass type filter is far superior. To reduce it to a few terms, we believe for the same type unit, that is the same type unit to handle the same capacity of air, you can probably construct fiberglass for about two-thirds the cost, you'll have about half the pressure drop and you'll reduce the amount of activity going to the atmosphere by a factor of five and the life of the filter is at least the same and probably double.

FIRST: I might add that there are excellent reviews of both the sand filter, by Lapple, and the deep bed glass filter, by Blasewitz, in the proceedings of the 5th AEC Air Cleaning Conference. These papers include cost estimates as of that time.

RIVERS: I have a question for Mr. Sims. I assume that the suggestion for tightening the filter sealing at the end of two weeks is to reestablish the initial gasket pressure. Is it not likely that in the next two weeks gasket pressure would decline to the low value, and that this process would be repeated indefinitely?

SIMS: Well, we don't believe so. We feel that upon recompression the difference between original gasket pressure and equilibrium pressure will diminish rapidly and thus the effect of gasket relaxation will also diminish.

RIVERS: Is there any intention to study this long term?

SIMS: No, not that I know of.

KESSIE: I have two comments which may have significant relationship to the future use of sand bed filters. First, is that the GE Midwest fuel reprocessing plant proposal includes the use of sand bed filters. Second, is that certain factors in connection with the ruggedness of the sand bed filters, such as chemical, heat and shock wave resistance may have significance in future applications.

FIRST: I have high regard for the performance of sand filters, but wish to point out that the area of usefulness is more restricted than that of the high efficiency filter. There are special circumstances which make the sand filter the preferred unit.

ALLAN: I would like to make an appeal to our AEC customers and also to our competitors, to work on a program of establishing certain designated type specifications. In other words, to have a common specification for a common type. The way things are now, each site writes its own specification and a particular type filter may be described, in fact usually is described, in about six different specifications all reading differently and all very confusing to the people such as myself who don't read very well!

I think this is quite unnecessary and if you go over the books, you will find there are really only two general filters used, possibly three and at the most five.

Now, I would not exclude odd-ball filters which have to be made of stainless steel or some other thing like that, but I think they should be a subject of separate specifications.

And, I think Dr. Anderson's group would be an excellent one to work on this problem. It would help the problem of reshipping filters which have been shipped which are not correct, or of the site accepting filters which they didn't want in the first place and also it would help the problem of the manufacturer in understanding correctly the writing of the specification, which is sometimes obscure, at least I think so. Thank you.

FIRST: Would you like to comment Dr. Anderson? If there are users who would like to comment on this point, they may speak after you.

ANDERSON: It is my opinion that Mr. Allan has a valid point. We have seen specifications from the various installations that differ only in minor areas yet require different media and/or different designs for fulfillment. Since we now have European makers to satisfy, this further complicates the picture. It is my opinion that we should establish a uniform specification for our domestic users and stick by it. For those relatively few users who have special requirements different from the specs, they could provide exceptions in their procurements. One has to realize that when you go beyond the overall specification, then you will have to pay for it. I believe that the acceptance of a generalized specification would give us additional economic benefits at no cost to performance.

BURCHSTED: I would just like to say that the group Dr. Anderson is with is the ad hoc committee that has been charged for several years with exactly that which Mr. Allan has asked for. I thought for a while we were going in that direction, but apparently we deviated again, so perhaps the group could get together again.

GILBERT: From the operating side of the AEC, there are just a few problems. We have a long range policy of hiring contractors who are reputedly competent in their field and do not require spoon-feeding.

We've followed this policy throughout the life of the organization. Now, this inquiry appears to raise a question as to whether the policy is wrong and it's not my point to question the policy. Also we have the factor of the industrial image-motivation of isolated contractors, leading to individuality of filter specifications, and the picture is somewhat complicated.

We put out the recommended set of minimum specifications for the filter. We don't expect this to cover every variety of use. We would expect the contractor to build on this for his particular needs.

Now, there's some possibility contractors may have overbuilt, but we have a situation we've been living with for a couple of decades.

BURLEY: I have a brief comment about Dr. Schwalbe's presentation; namely, the technique is good for determining elastic moduli, and the Youngs modulus is derived from these elastic moduli. However, the technique as you described it is really only applicable to either amorphous material or cubic material where the directional properties are isotropic. What we must consider here is that if we incorporate materials other than glass, the properties after elongation may not have direct correlation with the Youngs modulus as measured by this technique.

SCHWALBE: We have experience only with glass fiber media, and as you notice only a few. This is a new technique and I think it is very much in order that we have to check again when other materials are being used.

Of course, modulàr testing is used for many materials but I wouldn't want to make any sweeping statement what we can do for every conceivable media fiber, so it is better to restrict it to what we know.

THOMAS: I'll address this to Dr. Anderson. You mentioned you had a lot of information on penetration as a function of air velocity so I think I'll put you on the spot right now! As I recollect, the air velocity through the 1,000 cfm filters is five feet per minute, or 2-1/2 centimeters per second.

Now, would you be willing to tell the audience what is the aerosol size for maximum penetration at this velocity we actually use for a typical high efficiency filter media?

ANDERSON: If you will permit me to generalize, then I can give you a fair estimate. You must realize that the maximum penetrating particle size is a function of the filter, the aerosol, and the conditions of use. It is dependent on the size and density of the aerosol; the fiber diameter, interfiber distance and thickness of the filter; and the linear flow rate, temperature, and pressure of the air. These are the major variables although some lesser conditions such as electrostatic effects, humidity may enter in.

Our tests show that for glass filter media presently used in HEPA filters and for operation at ambient conditions at a flow rate of about 5 feet per minute, the maximum penetrating particle size for particles of unit density is somewhere between 0.05 and 0.09 microns; say about 0.07 microns.

THOMAS: I'm very glad to hear that, because I've been trying to drag the information like this out of you for years and now, of course, this way I'll get you on the record here of the meeting and not a private conversation!

ANDERSON: I think that if you will inquire you will find that other researchers, Dorman of England, Hassenclever of Germany among others, have arrived at the same values that we have. I believe that Hassenclever states his value under comparable conditions to be about 0.07 microns.

THOMAS: Well, I'm certainly looking forward to seeing your report. I assume it hasn't been published yet.

ANDERSON: There appears to be two separate types of researchers in the scientific community. One, accomplishes a lot of experimental work and accumulates a lot of useful data but doesn't interrupt his experimental program to report it. The other spends little time obtaining the experimental facts and then spends most of his efforts reporting them in numerous publications. Unfortunately I happen to be the former rather than the latter. The information that Mr. Thomas is referring to, he has observed in our data notebooks and curves. The data, I'm sorry to report has never been published. Mr. Thomas has even suggested that he might be available to organize the data and perhaps assemble it into a published book.

THOMAS: Well, how about the audience here? They want to see things like this in print. I think you're neglecting some of your obligations by not doing it.

ANDERSON: We will take Mr. Thomas' request under advisement and will do our best to convert our purpose in life from a doer to a reporter. In the meantime, if you feel that any of our raw data would be helpful in your research programs, please feel free to call upon us.

PELLETIER: My comments are directed to Dr. First. Let me say I am not directly involved in air cleaning technology and therefore my comments may be naive, but the two days at the U. N. building as well as this morning have helped me form an impression. It seems to me that the work in the United States is directed almost entirely to protecting and testing the filter that we have. Is there no work going on in this country to look for better filter efficiencies or is this 99.97 per cent absolute?

FIRST: I think the answer, as many of you here know, because you're working in this area, is yes. For example, we currently have a doctoral student at Harvard who is completing his thesis on mechanisms of air filtration which I think will be a significant contribution to the field. I could name many who have made significant contributions over the past fifteen years to the theory of air filtration and all of this is related to production of better filters. There's a practical aspect to this, also; when someone offers to purchase a better filter and writes specifications for it, I have complete confidence that the manufacturers will find a way to produce it. Improvement of commercially-available filters is inhibited by the fact that there is now no foreseeable payoff to the manufacturer for his development costs. As a matter of fact, if you examine filters currently sold, you will frequently find that penetration values are listed as 0.002%. This is far less than the specified limit of 0.03% and it should be kept in mind that this is new filter efficiency. Efficiency rises rapidly during the first few hours of exposure when the dust load to the filter is a few tenths of a milligram per cubic meter, or greater.

LINDER: My comments refer to your review this morning, Dr. First. You mentioned that the present trend in the development of absolute filters is to increase the area of filter paper within a specific filter test.

From the tests I reported yesterday, we could see that the increased filter paper area didn't give any special economy of the filter because the dust holding capacity decreased so the life time of the filter decreased too. Especially if the filter paper will be a combination of pre-filter and final filter, it's important to have enough space to allow dust to be accumulated in the filter. So I'm just wondering if there is any test that shows which the optimum filter area is that gives the maximum holding capacity.

FIRST: I don't know of any test that would answer your question specifically. I agree with you that a filter that would have larger storage capacity for dust with modest pressure rise would be an improvement. I also agree that the mere introduction of more paper in a filter isn't necessarily a benefit unless the filter has been especially designed to accomplish collection and storage in a way which will prevent a high resistance filter cake from forming on the filter paper surface.