Pulmonary emphysema is becoming progressively more important as a disease entity in veterans and general populations. This disease is manifested by parenchymal destruction and departitioning of alveolar spaces. The identification of the disease is important and is readily accomplished by routine pathology studies. How-

Lung Destruction Measured by Energy Transmission Through Fume Fixed Lungs*

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ever, quantitation of the degree of destruction in pulmonary emphysema requires more detailed observations, best performed by study of whole lung sections using techniques previously described.1,4

A convenient method for this quantitation would be to use whole sections of dried fume-fixed lungs. We used sections of this type to develop a visual grading system for varying degrees of change ranging from normal to severe destruction. This grading system involved a considerable degree of subjective impression, and correlation between different observers was possible only to a limited extent. Review of the sections by the two authors demonstrated individual variations in gross grading.4 Mitchell and associates5 used a gross grading system and divided their cases into four grades ranging from zero through 3 plus destruction. An accurate and reproducible means of measurement of lung destruction would be of considerable value if these measurements could be related to clinical and physiologic parameters. For example, an accurate measurement would be useful in evaluating the relationship between emphysema and chronic bronchitis.4,5 Additional value might be found in the development and evaluation of newer methods of measurement of emphysema in the living patient. Mechanical and physical measurements which would not depend on objective impressions were considered worthy of investigation.

Whole lungs were collected from necropsy material, inflated and fume-fixed. These lungs were weighed and their volumes

**Figure 2A:** Sound scanning equipment.  **Figure 2B:** Close-up view of sound source and microphone.
were measured by water displacement. They were then sectioned at 0.6 cm. to 0.8 cm. thickness in the parasagittal plane. Visual grading of these sections was carried out by modification of the method reported by Cromie' in 1961. A transparent grid inscribed with one inch squares was placed over the lung specimen and each square was graded for degree of destruction on a scale of 0-10. The degree of destruction for each section was determined by the average value of the squares.

Tungsten light, sound transmission at various wave lengths, and beta radiation

**Figure 3A:** Lung section, grade 1

**Figure 3B:** Lung section, grade 4

**Figure 3C:** Lung section, grade 6

**Figure 3D:** Lung section, grade 7

**Figure 3E:** Lung section, grade 8

**Figure 3F:** Lung section, grade 9

**Figure 3(A-F):** Representative sections demonstrating visual rank order of the degree of destruction.
were used to measure these fume-fixed lung sections. In all these methods, the section was placed on a specially constructed scanner frame support. The energy source and the detecting head were placed on opposite sides of the specimen and kept in opposition to each other by two cantilever arms. The energy used was directed through the lung to the detecting head to measure alterations in energy transmission. The energy source and detecting head were passed across the lung section by a mechanical screw mechanism. The limits of travel were set by two micro switches which reversed the direction of the screw device. At the end of each traverse, a catch was released permitting the supporting platform to be displaced downward for a distance of 7/16 of an inch. These two motions permitted 20 lines per scan, sufficient to cover the area of all the lung sections used (Fig. 1A-B).

Base line counts without a lung section on the scanner were done for each energy source. These base line counts were repeated at frequent intervals to insure accuracy and stability. A lung section was then affixed to the scanning frame by nylon filaments and the scan was repeated. The difference between scan of the lung and the base line count represented the energy absorption of each lung section. This method eliminated the need for masking material around the lung sections, and reduced the inherent possibility of error when calculating results. The surface area was measured by planimetry and the thickness measured by a caliper. The absorbed count per square cm. of each section was then calculated and this count assigned as the physical measurement of that specimen.

In the tungsten method an incandescent source consisting of a bullet substage microscope illuminator with a 6.3 volt lamp passed light through the scanner and lung section into an opposing photo emissive type photo tube with an S-4 spectral response. The variations in light intensity caused by alterations in lung structure were detected by the photo tube and amplified by a modified photovolt Model 501-M densitometer. A light range on the photovolt densitometer was selected to detect light passing through normal lung and which would also detect transmission through severely emphysematous areas. At lower sensitivity ranges, this device recorded only the area of the specimen because the section was regarded as opaque. The range used for our experiments was at a

![Figure 4: Comparison of light absorption with rank order of specimens.](http://journal.publications.chestnet.org/pdfaccess.ashx?url=/data/journals/chest/21438/)
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densitometer attenuation of 100x. A specially designed computer-counter sensed the densitometer output, summed this output and converted it into a total count. Reproducible counts per square cm. were obtained since the scanning time and rate were carefully controlled and fixed.

This equipment was also adaptable for sound transmission studies by substituting an Eico Model 377 audio signal generator for the light source and a modified Electro Voice Model 649 B low impedance dynamic microphone for the photo cell (Fig. 1 A-B). Energy from the sound generator was picked by the microphone amplified through a Bell amplifier, rectified and fed into the computer counter as a varying DC voltage of approximately 10 volts maximum. The computer counter was sensitive to changes in voltage which were proportional to the density of the lung specimen. The sound intensity was arbitrarily set at a level which would penetrate normal lung and still give a 0-10 volt DC response at the input to the counter when testing varying degrees of destructive change. The same scanner and computer-counter were used to obtain absorbed counts per square cm.

We selected 12.5 KC/sec. sound transmission as the routine frequency to be used because it was a practical frequency and was also one of the sound frequencies which resulted in good absorption by the lung section. Other frequencies which were used but not investigated in detail ranged from 0.5 KC/sec. through 22 KC/sec. Beta radiation was measured on the same scanner using an 0.2 microcurie thallium 204 source, a thin window, Geiger-Muller tube and a model 132B Nuclear-Chicago scaler. Base line and absorbed counts were obtained.

Representative sections of 38 lungs were ranked in order of degree of destruction by gross grid methods described above (Fig. 3). The energy absorption of these sections with light, sound, and beta radiation was then determined as previously indicated. The absorbed counts per square cm. of each section were then compared with the rank order in relationship to the other sections.

Beta radiation absorption using the method described above did not relate to degree of destruction. Severely destroyed lungs sometimes absorbed more beta radiation than normal lungs. It appeared that this type of beta radiation measured the

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**Figure 5:** Comparison of sound absorption with rank order of specimens.
density of the dried lung tissue, and the residual retained blood and exudate. Beta radiation was much less affected by the loss of tissue continuity in areas of emphysema. Other sources and other detection devices might possibly improve this technique. Beta radiation was not further investigated at this time.

Tungsten light produced a reasonably good correlation with rank order of degree of destruction (Fig. 4). It will be noted that the initial portion of the curve is almost horizontal for a number of specimens because all these sections were considered to be relatively normal. The subsequent portion of the curve with the steep slope represents decreasing absorbed counts with increasing degrees of lung destruction. The variations in thickness of the specimen within the range of 0.2 cm. had no apparent effect on light absorption. These observations have been rechecked several times, appear to be valid, and may be due to the fact that the lung is not a homogenous structure particularly when varying degrees of destruction are present.

Sound transmission studies were done on all the specimens which had been previously studied with tungsten light. Absorption of 12.5 KC/sec. sound was measured on these lung sections. When the results were plotted against rank order there appeared to be much less correlation than that previously obtained with light (Fig. 5). Sound transmission values seemed to distinguish between normal and severely destroyed lung. The intermediate degrees of destruction were not so readily measured.

It is not surprising that tungsten light absorption gives a fairly good correlation when compared with rank ordering of specimens insofar as degree of destruction is concerned. Rank ordering in this instance depends upon changes in the tissue as seen by the observer which permit varying amounts of light transmission. The greater the degree of destruction, the more light transmission will take place with reduction in the total absorbed energy. We had anticipated that pigment in lung sections, particularly hemoglobin, would reduce light transmission, but the effect, if any, was small and apparently not significant. This lack of effect might be due to the thickness selected since it was reasonably uniform, and allowed light transmission through apparently normal lung even in the presence of pigment. At this thickness, the light transmission was apparently the same through pigmented and non-pigmented areas. The differential absorption of the various wave lengths by pigment is a subject for possible future investigation.

The studies in sound transmission are interesting because a different type of energy was used, and because sound did correlate with the tungsten light findings in both normal and severely destroyed lungs. Other investigators have used ultrasound as a method for defining the outlines of organs and certain structural details. When applied to the lung, ultrasound is limited to the outline of solid structures. Ultrasound systems now available permit scanning of the surface of the lung and the immediate subsurface tissue, but do not appear to be of value in the analysis of deeper lung structures.

Refinements in techniques may possibly improve the results with sound. An important reason for pursuing sound scanning is that it might prove to be a clinically useful tool in the detection of early or minimal pulmonary destruction. Another use might be the evaluation or measurement of the degree of pulmonary change in the living person. We are currently investigating the use of lower sound frequencies in the range of 100-10,000 cycles/sec. as a means of scanning lung tissue in vivo.

**Summary**

Tungsten light, sound at 12.5 KC/sec. and beta radiation were investigated as a means of measuring degrees of lung destruction in inflated fume-fixed lung sections. A scanning and enumerating device is described which is capable of evaluating the entire section. Absorption of light ap-
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pared to give an adequate measure of lung destruction and correlated well with the rank order. Correlation of sound with visual degree of destruction was only fair. Beta radiation with the method used showed no correlation.

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