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STATEMENT BY THE P. LORILLARD COMPANY

- PHENOL IN CIGARETTE SMOKE AND ITS EFFECT ON CILIA

The Research Staff of the P. Lorillard Company became interested in the study of phenol and phenolic compounds following a survey of compounds that had been listed as present in cigarette smoke. A number of investigators had reported the presence of phenols in smoke. More recently, several reports of methods for its quantitative determination have appeared. In 1960 A.W. Spears of our laboratory developed an accurate quantitative method for the determination of phenol by using Carbon^{14} phenol as a radioactive tracer. This method, employing gas chromatography, was both rapid and accurate. Following this development, a large number of determinations were made of phenol and associated compounds that were present in cigarette smoke. The total amount of phenol found in unfiltered cigarette smoke was about two to three parts per thousand. Consequently, our research staff decided to investigate the presence of the phenolic group of compounds in various brands of cigarettes. There was a wide variation among brands, depending, among other things, upon whether the brand was filtered or unfiltered, and the efficiency of the filter employed. The result of this survey showed that in a leading non-filtered cigarette the phenol content was 105 micrograms per cigarette. In a leading filtered cigarette, it was found to be 35 micrograms per cigarette, and in our KENT cigarette, 24 micrograms per cigarette.

From the preliminary investigations, it was found that about 80% of the phenol occurs in the particulate matter, and the remaining 20% is found in the gaseous phase of cigarette smoke. It was also apparent that certain filters, such as the one employed on KENT cigarettes, removed more phenol than could be accounted for by that removed in the particulate matter and that in the gaseous phase. This was an indication to us that selective filtration was taking place. Repeated investigations showed that phenol could be removed selectively. Therefore, the following mechanism was postulated:

> The particulate matter of the smoke, similar to other aerosols, is generated by the condensation of vapor components on a solid particle as a nucleus. This phenomenon occurs in the formation of raindrops where water vapor condenses on dust particles. In the burning cigarette, the nucleus is probably a fragment of non-volatile matter, such as a carbon particle, trapped in the gas stream. Compounds in the vapor phase will condense on this nucleus in such a manner that there will be a gradient distribution of components from the least to the most volatile as one moves from the centre to the outer boundary of the droplet. Therefore, a volatile component, such as

phenol, will be concentrated at the surface of the spherical particle. This being so, it now becomes possible to remove the phenol as well as any other similarly volatile compound concentrated on the surface of the smoke particle.

With this in mind, we were able, by the addition to the filter of a special additive that would combine with phenol, to selectively and substantially reduce it in cigarette smoke. Materials having the ability to do this have been described in a patent application submitted by our staff members. The effectiveness of filters treated with a material of this nature was proven by the fact that where KENT, with untreated filter, had 24 micrograms per cigarette, KENT, with treated filter, had only 12 micrograms.

The importance of the reduction of phenol in cigarette smoke to a low level is indicated by reports in scientific literature describing the effect of cigarette smoke on the action of cilia.

Previous to our experimentation with the determination of phenol in cigarette smoke, we and others had been carrying on research concerning the action of cigarette smoke on cilia. The test material employed was the esophagus of the frog, in which the rate of movement of mucus is measured by observing the rate of movement of carbon particles floating on its surface. Other investigators have studied the effect of cigarette smoke on excised human respiratory cilia. Their results apparently parallel studies of cilia action in frogs. In each case, these studies indicate that cigarette smoke inhibits to a varying degree the action of the cilia.

Cilia, which look like microscopic hairs, are found in a wide variety of living organisms ranging from protozoa, clams and frogs, to the human being. These cilia move back and forth in a wavelike motion, and if the object to which they are attached is stationary, their motion will propel the surrounding medium, which in higher animals is a layer of mucus, over the surface of the cells. Thus, any particles trapped in the mucus, or on its surface, are moved along by the motion of the cilia.

In the frog, these ciliated cells line the mouth and esophagus. Their purpose here is to propel particles of food trapped in the covering layer of mucus into the stomach — a function analogous to the swallowing mechanism in higher animals. In the human being, moreover, these ciliated cells and the accompanying mucus-secreting cells maintain a relatively uniform layer of mucus over the entire inner surface of the breathing passages, which serves as a trap for pollen, dust and other foreign particles carried into the body with the inhaled air. The ciliated cells constantly move this mucus layer upward, thus preventing accumulation of foreign materials in the respiratory system.

Various materials, including cigarette smoke, have been reported as interfering with this mechanism. It has been demonstrated that the mucus flow rate on the excised frog esophagus and in the tracheae of laboratory animals can be slowed or stopped by phenol and various other chemical agents. A similar effect was reported with ordinary cigarette smoke. We have been able to show in our laboratory that the effect is not a non-specific response, as has been previously reported, but that it is the result of only certain chemical agents rather than a physical response to any and all foreign materials which might come in contact with the ciliated tissue.

Through our studies of the composition of cigarette smoke, and our concurrent cilia work, we have been able to establish phenol and phenolic type compounds as the factors in cigarette smoke mainly responsible for the cilia-depressing effect of the smoke. Our data, based on the rate of mucus flow over an excised frog esophagus, shows that the greater the amount of phenol present in the smoke from a given cigarette, the greater the reduction of the mucus transport. This relationship is clearly established by our laboratory finding that the rate of mucus flow is unaffected by the smoke from KENT cigarettes with the new selective "Micronite" filter. Under the controlled conditions of the experiment, the rate of flow of the mucus after exposure to KENT is exactly the same as the rate of flow when the cilia are exposed to laboratory air, whereas the rate of flow of the mucus when exposed to the smoke of another leading filtered cigarette is approximately 67% slower and the rate of flow when exposed to a leading non-filtered cigarette is approximately 85% slower.

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