DEVELOPMENT OF A LABORATORY RADIANT COMBUSTION APPARATUS FOR SMOKE TOXICITY AND SMOKE CORROSIVITY STUDIES

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A new laboratory apparatus has been developed and been shown to be useful for evaluating either the toxicity or corrosivity of the smoke produced from actual products. The apparatus features radiant heat combustion of the specimen and collection of all of the smoke produced. Three important fire parameters may be determined using this apparatus. They are: 1) time to ignition, 2) rate of smoke evolution, and 3) characterization of the smoke (e.g., toxicity or corrosive effects). These may be evaluated as a single, measured test parameter or determined independently and then combined mathematically. The parameters determined in this test method may be used to help estimate the hazard of a product in an actual fire scenario by using computer fire models.

The apparatus is shown schematically in Figure 1. It is an improvement on an earlier radiant furnace smoke toxicity test device (1), which was a modification to the NBS (now NIST) "cup" furnace toxicity test apparatus (2). The unique aspects of this apparatus compared to others currently in use may be summarized as follows:

1. A relatively large size specimen can be used and radiant heat of up to 70 kw/m^2 is applied to the top face of the specimen, permitting testing of actual products (even composite products) in addition to raw materials.

2. An enclosed combustion/exposure system permits collection of the total amount of smoke produced from the specimen.

3. Continuous mass-loss measurements are obtained.

4. The radiant heat system permits essentially instantaneous heat radiation to the specimen and adds a minimal amount of heat to the enclosed chamber.

5. The combustion atmosphere may be modified before or during the combustion and/or exposure phases of an experiment (e.g., by controlling the oxygen concentration).

6. The combustion cell can be isolated from the exposure chamber by a shutter in order to terminate the combustion phase of an experiment. Thus, the smoke becomes isolated from (and therefore is no longer influenced by) the specimen residue or the hot combustion cell.

7. The smoke in the exposure volume is available for:
   a. analytical measurements, including those requiring a long sampling time and large sampling volume;
   b. toxicity determinations, including those under "steady state" smoke conditions;
   c. corrosivity measurements, even those utilizing large or multiple targets; and
   d. almost any other physical or chemical characterization of an accumulated quantity of smoke.

A plot of a typical smoke concentration vs. time curve (in this case, Douglas fir) is presented in Figure 2. The processes that occur during the test procedure are illustrated in this figure. At zero time, the radiant lamps are turned on to irradiate the specimen, which is located on the sample platform within the combustion cell. After some period of time, the specimen ignites (t_{ig}). Generally, the mass loss rate is not very high until ignition. After some predetermined time interval, the radiant lamps are turned off and the smoke shutter is closed. This is the "irradiation time" (IT). From that point on, the smoke concentration (and that of any non-condensible gases) remains essentially constant until the end of the test (e.g., 30 minutes).

The three key parameters determined in this test method are illustrated in the figure. The time to ignition is shown. The mass loss rate is illustrated by the slope of the line of smoke (or gas) concentration for the time between ignition and the stopping of combustion (generally at the irradiation time). Characterization of the smoke is conducted on the quantity of smoke or gas evolved.

A test method may be conducted in this apparatus under at least two different procedures. In one, a fixed quantity of specimen (e.g., 7.5 cm x 12.5 cm, 3 in. x 5 in., which is the largest practical size) is used, with a variable irradiation time (IT). Combustion is generally stopped at relatively short IT's (anywhere from one minute to perhaps 10 minutes). This smoke may represent the "early" smoke produced from a specimen under this test. In another procedure, the quantity of specimen is varied and the IT is fixed (e.g., at 15 minutes). This procedure tends to bake small specimens for a longer time than in the other procedure and the smoke would be a mixture of all products produced from the specimen over the time duration.

A hazard "index" for the first test procedure could be reflected by the IT required to produce an atmosphere that gives a set response (e.g., a particular toxic or corrosive end point). An alternative method, applicable to either test procedure would be to develop independently the three primary variables developed in this test procedure: ignition time (t_{ig}), mass loss rate (MLR) and a number characterizing the smoke (SC for "smoke characterization," e.g., an LC_{50} for toxicity measurements or some corrosive end point). These three may be combined mathematically to produce a simplified index of toxic hazard, such as the following equation:

$$\text{Toxic Hazard Parameter} = \text{Function of } [MLR/(T_{ig} \times SC)].$$

The full potential for this apparatus has not been examined experimentally. The apparatus offers the unique ability to control the

atmosphere (oxygen concentration) during the burning process in an enclosed system. The ability to stop combustion at any time during the burning in order to examine the smoke produced (or even to isolate a quantity of smoke in the middle of the burning process) is a further very desirable feature. Physical collection of the smoke, without having to resort to synthesizing the total smoke volume, along with knowing the mass of that smoke, is important for physical, chemical or biological characterization of the smoke.

The question still remains whether or not one can simulate a realistic large-scale fire environment in this (or in any) laboratory apparatus. There is a tendency to believe that application of a relatively high heat flux, such as produced in large scale fires, will automatically simulate that particular large scale fire environment. In fact, when smoke toxicity considerations are paramount to the testing, the oxygen availability may be a more critical factor than the applied heat flux.

REFERENCES

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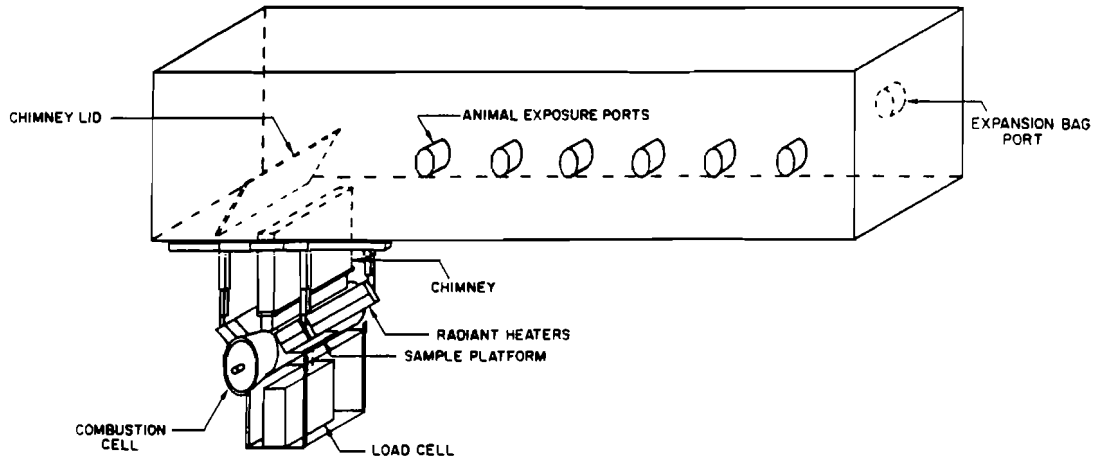

Figure 1. Schematic Drawing of Radiant Combustion/Exposure Apparatus

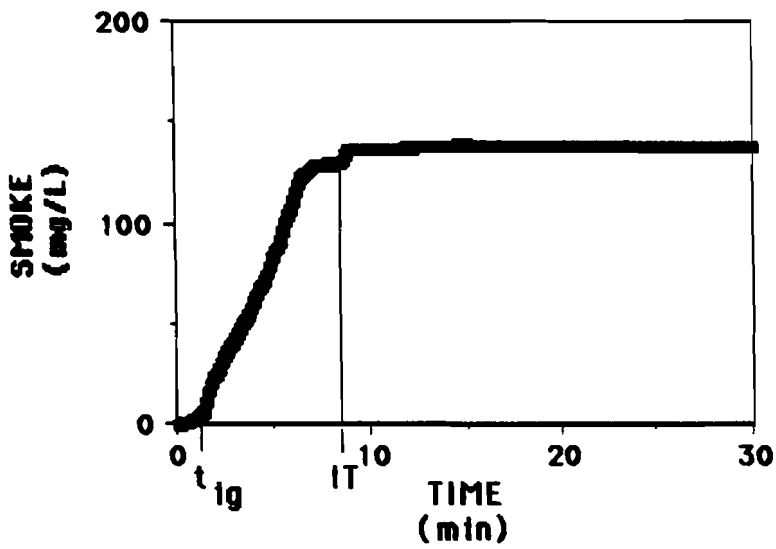

Figure 2. Typical Smoke Concentration - Time Curve