7 AEROSOL FLAMMABILITY

THE FLAMMABILITY of aerosol products has always been an issue of primary importance to the industry. In the U.S.A., starting about 1977, it assumed even greater dimensions as the non-flammable chlorofluorocarbons (CFCs) had to be virtually abandoned due to federal regulations, and were largely replaced with intensely flammable hydrocarbon gas liquids. Finally, in 1980, the Factory Mutual Research & Engineering Corp., owned and operated by four major insurance companies, conducted a series of large-scale fire tests using palletloads of aerosols and concluded that most warehouses did not have sufficient sprinkler-system protection to safely store a majority of aerosol products. An overview assessment suggests that the flammability of aerosols is one of the most pressing and important issues that the industry must address during the 1980s.

In the U.S.A., the earliest aerosols were the insecticide "bombs", developed in 1943 by Lyle Goodhue and William Sullivan of the U.S. Department of Agriculture. They were formulated with 85 to 90% P-12 in order to obtain a very fine particle size for maximum killing power. Because of the very high CFC content they were non-flammable under any reasonable condition of use. When the first disposable-can aerosols came along, about 1947, pressure limitations imposed by the Interstate Commerce Commission (ICC) required the use of at least 80% CFC propellents to produce a space-type spray. As a result these insecticides and room deodorants were also considered non-flammable.

But, by the end of the 1940s, several other products had entered the market. They included hair sprays and paints, products designed to produce a somewhat heavier, coating-type spray. They used only 60 to 65% CFC propellents. In early 1950, a fire chief in Buffalo, NY demonstrated the flammability of a hair spray by lighting the spray plume with a match during a lecture on product safety. The experiment got out of hand when a curtain behind the podium ignited, to the supreme embarrassment of the speaker and to the delight of several reporters in the audience. The resulting publicity brought the aerosol industry face to face with the the flammability issue.

Within a few months a Flammability Committee was formed within the new Aerosol Division of CSMA. Its purpose was to develop test methods and guidelines for aerosol flammability. They worked closely with Dr. John McKenna of the Bureau of Explosives, of the American Association of Railroads, and with Dr. "Bus" Fulton of the USDA, finally developing three mutually complementary test methods, specific for aerosols. In their capacity as an advisory technical body to the Interstate Commerce Commission, the Bureau of Explosives recommended that test methods and definitions be added to the Commission's official tariff, which described regulations for the interstate transportation of dangerous goods. This was done in 1952.

As succinctly as possible, the three methods may be described as follows:

a. *The Flame Propagation Test*
An aerosol is "Flammable" if it produces a flame elongation of 18" (457 mm) or greater when sprayed through the top third of a candle flame from a distance of 6"(152 mm).

b. *The Closed Drum Test*
An aerosol is "Flammable" if, when sprayed through a 1" (25 mm) port into a closed, horizontal 55 gallon (200 liter) metal drum with a lighted candle at the bottom, a "whoof" or large, rapid burning of the vapor/air mixture occurs within 60 seconds.

c. *The Open Drum Test*
An aerosol is "Flammable" if, when sprayed at a candle flame within a horizontal, open-end 55 gallon (200 liter) metal drum from a distance of about 36" (914 mm), a gross enlargement of the flame occurs.

At first the "Flammable" aerosols were not permitted in interstate shipment, but as more and more viable products of this type were developed in various laboratories, the need to ship them became more acute, and chemists started to use low delivery rate and vapor-tap valves in order to control the sprays so that they could pass the tests.

In 1954 the bug killer (75% petroleum distillate and toxicants,plus 25% P-12) was developed, but even with the most propitious valve adjustments it easily failed all three tests. Following a special industry meeting in Chicago, a group approached the ICC about mid-1954 and was able to persuade them to allow such products in interstate commerce, provided the flash point, by a low-temperature modification of the standard Tagliabue Open Cup method, was 20°F (– 6.7°C) or higher. The outer shipping cases also had to carry a red, diamond-shaped "Flammable" product label.

With this relaxation in the regulations, large numbers of red-labeled aerosols began to flow through channels of trade. The 20°F (–6.7°C) temperature selection was actually designed to permit the use of acetone and solvents of higher flash point, but to prohibit the interstate transportation of diethyl ether engine starting fluids. Hydrocarbon propellents were virtually unknown in 1954, so the flash point proviso had almost no limiting effect on the industry at that time.

But, in 1955 isobutane entered the aerosol scene, being first used in "Bon Ami" window cleaner at a level of 3.0%, and in conjunction with the mechanical break-up valve, first developed by Walter C. Beard, Jr. of Risdon Manufacturing Co. during the preceding year. The flash point test could not be meaningfully conducted on this product, because the large amount of water in the concentrate froze when the aerosol was equilibrated to –20°F (–28.8°C) prior to opening the unit. In any event, running this test was unnecessary, since the standard triad of flammability tests were all passed by the product. This development set the stage for the introduction of similar products: aerosol starch in 1955, aerosol multi-purpose cleaners in 1956, aerosol oven cleaners in 1957, and so forth, all with about 2 to 5.5% of hydrocarbon propellent and large amounts of water.

Blends of hydrocarbons and CFCs were then used,not only for hair sprays, but for penetrating oils, personal deodorants and a number of other products. They could be purchased directly from the CFC producers. Two of the more common were identified as Propellent A (45% P-12, 45% P-11 and 10% isobutane) and Varisol IV Propellent (52.4% P-12, 37.0% P-11 and 10.6% isobutane — to which various amounts of methylene chloride were sometimes added as the fourth component during the filling process).

During 1961 S.C. Johnson & Son, Inc., introduced their lines of "Raid" insecticides and "Glade" air fresheners in a water-based form. A number of similar formulations were launched by other marketers during

1962 to 1964 as a response, since the economic advantage was so overwhelming. Typically, these formulations had 28 to 34% hydrocarbon (A-31 to A-46), less than 10% of oil-based concentrate and the balance of water, plus traces of emulsifier and corrosion inhibitor(s). They were still non-flammable, although just barely so in many cases.

They owed this accomplishment to the use of low delivery rate valves having vapor-tap features. The success of these new formulations sensitized the rest of the industry to the fact that valve modifications represented an important way to get around the three flammability tests and market products as "not flammable", which actually contained a rather high level of flammable ingredients.

The Federal Hazardous Substances Act of 1960 was passed by Congress about this time, and the FDA was charged with the administration requirements. On Aug. 14, 1961 they published their Final Order (26 *Federal Register* 191) covering definitions and procedural and interpretative regulations. Part 191.1(1)(1 & 2) promulgated the first federal definitions ever established specifically for "Flammable" and "Extremely Flammable" aerosols:

> *Flammable Contents.* Contents of self-pressurized containers are "flammable" if when tested by the method described in pph. 191.15 a flame projection exceeding 18 inches is obtained at full valve opening or a flashback (a flame extending back to the dispenser) is obtained at any degree of valve opening.
>
> *Extremely Flammable Contents.* Contents of self-pressurized containers are "extremely flammable" if when tested by the method described in pph. 191.15, flashback (a flame extending back to the dispenser) is obtained at any degree of valve opening and the flashpoint, when tested by the method described in pph. 191.16, is less than 20°F.

The scope of the Act was limited to household products. It did not cover economic poisons, foods, drugs, cosmetics or fuels. On the other hand, the industry quickly used the results of these tests as a guide for the precautionary labeling of all aerosol products. While the safety of the consumer was the central concern, another factor was that marketers could protect themselves more adequately in product liability suits if they could state that their products were labeled in accordance with government requirements for similar products, in the absence of any regulations specifically for the product in question. This concept is still being used in the defense of suits brought against personal products, since the FDA has yet to establish any labeling regulations relating to the flammability of aerosol foods, drugs or cosmetics.

If an aerosol product falling under the FHSA is classified as "Flammable", the regulations require the statement "WARNING — Flammable" (or "CAUTION — Flammable", optionally) to appear on the principal panel. The signal word must be in 18 point type, while the statement of hazard must be in 12 point type. An exception, down to 6 point type, may be made for small containers. Supplemental statements are also required. The minimum would be: "Keep away from heat, sparks or open flame. Use with adequate ventilation." These words may be on the front, back or side panels, in type size of normally 10 point. If they do not appear along with the signal word and statement of hazard on the principal panel, then some statement such as "See back panel for additional cautions." must appear below these words.

Similarly, if a product is classed as "Extremely Flammable", the regulations require the statement "DANGER — Extremely Flammable" to appear on the principal display panel. All the other provisos given in the preceding paragraph then apply also.

When the Consumer Product Safety Commission (CPSC) was formed in 1972, the Congress declared that they should assume the administration of the regulations under the FHSA. Accordingly, in 1973 the regulations were revised and transferred [CPSC Ch. 2, C, 1500(c)(6)(v & vi)]. The revisions were minor and did not affect aerosol flammability sections.

During the mid-1960s the ICC, now a segment of the newly created Department of Transportation, established that the excellent safety record in the shipping of aerosols warranted a benevolent relaxation in their regulations. Three separate things were done:

a. The red, diamond-shaped "Flammable — Danger" label could be removed from the outer shipping cases of all metal aerosol units, up to can sizes of 35 cu. in. (573.5 ml) overflow capacity.

b Flammable aerosols in metal container were permitted for shipment even if the contents had a TOC flash point below 20°F (-6.7°C).

c. The Open Drum Test was abandoned, since it had little or no practical significance.

The concessions had a stimulating effect upon the industry. After a time it became obvious that the safe shipping record was still being maintained, and in 1976 the DOT acted to substantially revise the entire fabric of their shipping regulations. Over 99.8% of all aerosols were presumed to fall under the new "Consumer Commodity ORM-D" classification, which applied to all aerosol packages weighing under 29.5 kg (65 lbs) and where the product was either a consumer commodity or an industrial/institutional item for which there was a practical consumer counterpart sold domestically. The other 0.2% or less were I/I items for which there was no consumer equivalent, such as metal lay-out dyes and refrigeration system leak detectors. Under ORM-D, aerosols could be shipped without restraint as to flammability status or metal container size, up to the 50 cu. in. (819 ml) limit. Strictly I/I type aerosols still had to be marked with red "Flammable" labels if the dispenser size was over 35 cu. in. (573.5 ml).

The ORM-D term meant "Otherwise Regulated Material — Class D" and was applied only to ground transportation. For air transport the related term "Consumer Commodity ORM-D-AIR" was used, and a few additional regulations also came into play. On a practical basis, despite the permissive DOT position, those wishing to transport flammable aerosols by air will find that commercial airlines have very strict corporate or union-originated rules which often make it impossible, impractical or extremely expensive to make such shipments. The shipment of a few pounds of flammable aerosols between the U.S.A. and Europe by a freight-carrying (non-passenger) airplane could easily cost over $100 in 1982.

In the special situation of glass, plastic-coated glass and plastic aerosol containers, the DOT have elected not to relax their original regulations, since they were rather concerned about the possible hazardous effects of product breakage, during an accident or as the result of rough handling. In general, these aerosols are not permitted in interstate shipment if their contents are "Flammable" and have a modified TOC flash point of 20°F (-6.7°C) or less, provided the dispenser has a capacity of over 4 fl. oz. (118.2 ml). Aerosols of less than 4 fl. oz. (118.2 ml) capacity are exempted from pressure limits, flammability considerations and all other DOT regulations, provided the contents are non-poisonous.

With the virtual demise of CFC propellents in the U.S.A. after 1977, the glass aerosol segment of the industry suffered a particular problem in that many of their standard size bottles were over the 4 fl. oz. (118.2 ml) limit. They could not be shipped interstate or abroad if they contained formulations utilizing a hydrocarbon propellent and were classed as "Flammable". A few products, such as foams, quick-breaking foams and other high water content formulas, could be propelled with hydrocarbons and still remain non-flammable, but probably 98% of all large size glass, plastic-coated glass and plastic aerosols were banned from interstate shipment on the basis of flammability.

About 1980 the Wheaton Aerosols Company (the sole U.S.A. producer of plastic-coated glass aerosols) decided to meet this restriction head on. After exhaustive testing they were able to prove that their popular nominal 4 fl. oz. Boston Round aerosol bottle, with Lamisol plastic tri-layer coating, was extremely resistant to breakage, and that even if it did break, the rate of product release was either nil or negligible for a long time thereafter. This bottle has a capacity of 4.67 fl. oz. (138.0 ml). After a review of the data the DOT authorized a special exemption for this particular coated bottle. Any customer using the bottle is automatically covered by the exemption.

During the 1970s the U.S. Environmental Protection Agency (EPA) also developed flammability regulations. The first phase came about as a public notice, under the aegis of the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA). It was little more than a jumble of words, ambiguous and impossible to interpret with confidence. But then, about mid-1975, revised definitions and labeling provisions were promulgated in the form of revisions to the Federal Environmental Pest Control Act regulations (FEPCA).

Under FEPCA, if an aerosol *concentrate* has a modified TOC flash point of 20°F (-6.7°C) or less and the finished aerosol has a flashback (a flame extending back to the dispenser) at any degree of valve opening, then a label statement is required which reads, "Extremely Flammable. Contents under pressure. Keep away from fire, sparks and heated surfaces. Do not puncture or incinerate container. Exposure to temperatures above 130°F may cause bursting." (130°F equals 54.4°C). The precautions may be placed on the side or back label panel if desired.

Similarly, if the aerosol *concentrate* has a modified TOC flash point above 20°F (-6.7°C) but not greater than 80°F (26.7°C), *or* if the flame extension is greater than 18" (457 mm) when the finished product is sprayed through the top third of a flame from a distance of 6" (152 mm), then a label warning statement is required which reads, "Flammable. Contents under pressure. Keep away from heat, sparks and open flame. Do not puncture or incinerate container. Exposure to temperatures above 130°F may cause bursting." (130°F equals 54.4°C.)

In contrast, for all other pesticides a warning label statement is required which reads, "Contents under pressure. Do not use or store near heat or open flame. Do not puncture or incinerate container. Exposure to temperatures above 130°F may cause bursting." (130°F equals 54.4°C.)

These required pesticide precautionary statements normally appear on the side or back panels, and type size is determined by that of the other printed matter, available space and other factors.

But in no event shall the type size be smaller or less distinct or less contrasted with the background than that of the other printed material. In at least one instance, a pesticide was seized by the EPA because the precautionary language was uniquely inscribed in dark blue over a metallic blue background, making it excessively hard to read. The marketer agreed to paper label the unsold dispensers, changing the disputed area of the metallic blue color to white.

Aerosol Flammability Regulations in Japan

In Japan all aerosols are produced, labeled and sold under the jurisdiction of the High Pressure Gas Control Law of 1951 but broad exemptions are provided when the products conform to later Ordinances and Notifications of the Minister of International Trade and Industry (MITI). Typical general requirements for both flammable and non-flammable products are as follows:

a. The amount of propellent is limited to 500 g per container.
b. The product volume is limited to 90v% of the container at 95°F (35°C).
c. Containers with a capacity over 100 ml must be cylindrical, with an inner diameter not over 3.15" (80 mm) and made of steel or light metals. An exception is containers for P-12, which are limited to a bore of 3.00" (76 mm).
d. Metal containers shall not have a thickness below 0.008465" (9.215 mm). Note: this corresponds to the minimum thickness of 81-lb baseweight plate, as made in the U.S.A.
e. The maximum pressure for liquefied propellents or blends is 114 psig at 95°F (8 kg/cm² or 786 kPa at 35°C), and that for compressed gases (as CO_2) is 143 psig at 95°F (10 kg/cm² or 986 kPa at 35°C).
f. Metal containers shall not deform irreversibly at pressures less than 186 psig (13 kg/cm² or 1.282 MPa).
g. Metal containers shall not burst at pressures less than 214 psig (15 kg/cm² or 1.476 MPa).
h. Metal containers shall not exhibit gross leakage below 118.4°F (48°C).
i. Insecticides are limited to 250 g of contents and may contain up to 56% of methylene chloride.
j. Formulations must be non-toxic and non-corrosive to the dispenser.
k. Glass aerosols are limited to 100 ml capacity and must be plastic coated.
l. The name or symbol of the manufacturer, the production lot number, and the precautions of use must be listed on the label of aerosols having a capacity of over 1.00 fl. oz. (30 ml).
m. All aerosols must be hot-tanked so that the contents temperature is raised to within the range of 115 to 122°F (46 to 50°C), but no higher.

Aerosol cosmetic products specified in the Pharmaceutical Law are permitted to contain up to 10% flammable propellents, but only if the water content is over 40% and the product is dispensed as a foam or paste. Activities are now being carried out under the aegis of the Aerosol Industry Association of Japan (AIAJ) to have this rule (Notification No. 291 of MITI, 1974) relaxed in order to permit hydrocarbons and dimethyl ether to be used more adequately for such products.

The precautionary labeling of aerosol products according to five levels of relative flammability is regulated under Notification No. 557 of MITI, 1968. Flammability is assessed on the basis of two tests: the Flame Projection Test (similar to the U.S.A. method, except that a gas burner must be used) and a modified Closed Drum Test. The Japanese "explosion chamber" is a horizontal cylinder of 11.9 to 14.5 gallon (45 to 55 liter) capacity, equipped with a fan and a sparking or

*While these requirements are current in 1982, the AIAJ advises they are under extensive review and may be completely revised. Firms wishing to determine current regulations after 1982 should contact the AIJA or the Japanese Embassy for information.

ignition plug. A loose-fitting lid closes off one end of the chamber and the other end carries a small port for spraying the aerosol into the drum. Spraying is done for one second at a time, with two seconds in between. When a "poof" or mild explosion occurs, the weight loss from the aerosol can is measured and the Explosive Concentration (E_C) is measured as the weight loss in grams divided by the volume of the chamber in liters. The required precautionary labeling consistant with the results of the two tests is shown in Table I.

Experiments in the U.S.A have shown that the results of the Japanese Closed Drum Test can be duplicated with the U.S.A. 55 gallon (200 liter) regular Closed Drum device, provided a spark plug is used instead of the conventional candle flame, since the flame actually burns up a portion of the flammable vapor during the test, making the results apparently less critical.

TABLE I

Flammable Aerosol Classifications and Precautionary Labeling in Japan

Test Result	Classification	Precautions
E_c = over 3 g/1 and F.P. = 0" max.	Non-flammable	Do not keep at temperatures over 40°C Do not throw into fire after use.
E_c = Over 1 g/1 and F.P. = 2" (50mm) max.	Not easily flammable	As above.
E_c = Over 0.25 g/1 F.P. = 10" (250 mm) max.	Slightly flammable	Do not direct toward a flame. Do not use large amounts near a fire. Do not keep at temperatures over 40°C Do not throw into fire after use.
E_c = Over 0.13 g/1 and F.P. = 17.7" (450mm) max.	Moderately flammable	Do not apply toward the human body. Do not use near fire. Do not use large amounts where a flame is also present in the room. Do not keep at temperatures over 40°C Do not throw into fire after use.
E_c = Below 0.13 g/1 or F.P. = over 17.7" (450mm)	Highly flammable	Do not apply toward the human body. Do not use near fire or in houses where flames are also present. Do not store at temperatures over 40°C Do not throw into fire after use.

Aerosol Flammability Regulations in Europe

In Europe, aerosols are produced and sold under the laws of individual countries, but may be transported or exported under various international regulations. Typical general regulations which apply to both flammable and non-flammable aerosols are as follows:

a. European Economic Community (EEC) regulations apply to metal cans from 50 to 1000 ml capacity, to plastic coated or otherwise permanently protected glass containers from 50 to 220 ml capacity and to frangible glass or plastic containers from 50 to 150 ml capacity. Dispensers larger than these sizes are not permitted.

b. The product volume is limited to 95v% of the container at 122°F (50°C) if the can has a deformable concave base; otherwise it is 90v%. For aerosols normally stored in cars this may decrease to 85v% in some countries. The dispenser should not become liquid filled at temperatures less than 158°F (70°C).

c. Containers of metal having an outside diameter of 1.575" (40 mm) or greater must have a concave base. (U.K.)

d. For containers having products where the pressure is less than 97.2 psig at 122°F (670 kPa at 50°C) the test pressure resistance must be at least 145 psig (1.000 MPa). For containers holding products with pressures higher than that, the test pressure resistance must be at least 50% higher than the pressure at 122°F (50°C) for liquefied propellents and 33.3% higher than the pressure at 122°F (50°C) for compressed gases. (EEC — 1975)

e. The maximum pressure for liquefied propellent formulas is 116 psig, and for compressed gas formulas is 130.5 psig at 122°F (800 and 900 kPa resp. at 50°C). (EEC - 1975)

f. Aerosols must be hot-tanked so that the contents temperature rises to at least 122°F (50°C), or the pressure becomes equivalent to the equilibrium pressure of the contents at that temperature.

g. Contents are declared as average volume, expressed only in metric units. An exception is made for U.K. cosmetics, which presently may be labeled in both metric and imperial units of weight and/or volume. This will probably change soon.

Around 1966 the Federation of European Aerosol Associations (FEA) settled upon a definition of flammability based upon the weight and percentage of combustible components in the aerosol formulation. Specifically, they recommended that aerosols containing more than 45% by weight, or more than 250 g of flammable contents should be labeled ''Flammable. Do not use near fire or flame.'' The flammable ingredients (interchangeably called both inflammable and combustible in Europe) were those having a flash point of less than 212°F (100°C), using the Tagliabue, Abel, Abel-Pensky or Luchaire-Finances closed cup testers.

Shortly afterward the Reglement International Concernant le Transport de Merchandise Dangereuses par Chemin de Fer (RID) adopted the definition for purposes of railroad transportation in Europe. They allowed both types of aerosols without restraint, even for railroad express shipments.

About 1969 the Accord Europeen Relatif le Transport International Dangereuses par Route (ADR) also adopted the definition for purposes of truck transportation in Europe. Aerosols were grouped into the danger category, Class 2, Part E, and differentiated as follows:

a. Non-flammable aerosols.

b. Flammable aerosols.

  i. Those with less than 45% by weight of flammable material.

  ii. Those with more than 45% by weight of flammable material.

Their regulations (No. 2208, 2209 and 2210) specify the conditions required for transport, such as container markings, fill amount and so forth. They are in harmony with the latest revisions of the Technical Regulations for Pressurized Gases (TRG 300 — West Germany) and other national and international regulations.

At about the same time the International Maritime Consultative Organization (IMCO), developed regulations for shipping purposes, now known as the International Maritime Dangerous Goods Code (IMDG), which is more complicated than the RID or ADR regulations, but where the percentage of flammable ingredients is still used for the classification of aerosols. Four classes are used, according to relative flammability:

a. Class 2: (Gases) Aerosols containing more than 10% flammable gases.

b. Class 3: (Flammable Liquids) Aerosols containing either more than 45% flammable liquids and no flammable gases, or those containing more than 35% flammable liquid in the presence of flammable gases.

c. Class 9: (Various Dangerous Materials) Aerosols containing no flammable gases but more than 10% of flammable liquids.

The International Air Transport Association (IATA) publishes air transport regulations. So far they have adhered to the U.S.A. and Canadian methods of defining flammability on the basis of the properties of the aerosol, rather than the composition. However, if aerosols contain flammable gases or liquids, a prescribed red flame-symbol label must be affixed to the outer case. Conversely, aerosols containing non-flammable gases must carry a green label on the shipper.

Around 1968 a concerted effort was made, led by Dr. Werner Lessenich in Europe and the author in the U.S.A., to harmonize the divergent approaches to aerosol flammability in these two areas, which at that time accounted for about 86% of the world's aerosol production. Some 350 cans were tested for both flammable content and flammability in Europe and about 250 cans were evaluated in the same way in the U.S.A. Using the European 45% flammables dividing point, there was a 74% agreement (non-flammable by test = below 45% flammables, and flammable by test = above 45% flammables), with an additional 23% classed as non-flammable by test but flammable in Europe, and 3% flammable by test, although having less than 45% flammable ingredients. By moving the dividing point to 55% flammables the results per 85%, 10% and 5%, resp. and by adjusting to 56.5% flammables the results became 87%, 8% and 5%, resp. This last result was the one that showed the greatest agreement possible between approaches.

A number of U.S.A. aerosols were non-flammable according to the flammability tests, yet they contained well over 45% flammable ingredients. This was due to the use of low-delivery rate valves, based upon either small orifice or vapor-tap features, or sometimes the addition of methylene chloride as a flame suppressant in the flame projection test. Neither of these expediencies were much used in Europe at the time. Now they are. In fact, the heavy usage of methylene chloride as a vapor pressure depressant, flame depressant and solvent has engendered numerous regulations there. For example, in solvents, paints, varnishes and glues, if more than 10% is used, the label must have a St.

Andrews (diagonal) cross, plus the phrases "Harmful vapor. Avoid contact with the skin, eyes and clothing." In pesticides, if more than 20% is used the label must state "Contains_____% methylene chloride"; but in cosmetics up to 35% is permitted and no warning phrases or symbols are required.

A provisional decision was made by the FEA that they would try to persuade the RID and ADR organizations to accept as "Flammable" those aerosols which either contained 55% or more of flammable substances or were flammable according to the test methods used by the ICC in the U.S.A. But, it was predicated on approval of the same criteria by the ICC. The proposal was presented to the Flammability Committee, Aerosol Division, CSMA where it met with strong minority resistance. Subsequently, it was discussed informally with Mr. Roberts, the Secretary to the ICC commissioners, who turned it down, since he did not like any "either/or" regulations. As a result, the proposal failed and the two leading producers, Europe and North America, are now unalterably committed to their different approaches toward the definition of aerosol flammability. At least to date, the dichotomy has not had any significant ill-effects on the industry.

During the past several years, European aerosols have inexorably moved toward compositions containing higher levels of flammable ingredients. This has been due not only to bans, threats of bans, 30% voluntary reductions and other sanctions placed upon the use of CFCs due to the CFC/ozone controversy, but also because alternate propellents such as the hydrocarbons and dimethyl ether (DME) are much more economical. The transition can be seen in Table II which shows large increases in the flammable content of aerosols in both the U.S.A. and the U.K. during the period 1976 through 1981.

It is anticipated that, during the 1980s, the flammable content of virtually all anhydrous or low-water content European aerosols will rise well above the 45% mark, causing about 75% of the overall production to be considered "Flammable".

The British have recognized that the U.S.A., IMDG and other entities have established two or more levels of

TABLE II

Flammable Contents of Aerosols Produced in the U.S.A. and the U.K. (1976 and 1981)

Country	Year	Product Category	Production (Millions)	Per Cent Flammable Content 0-20	20-40	40-60	60-80	80-100
U.S.A.	1976	Antiperspirant	298	98	2	0	0	0
		Personal Deod.	107	0	5	70	25	0
		Hair Sprays	289	0	3	96	1	0
		Other Personal Products	287	55	1	27	17	0
		Household Products	1,069	26	21	3	5	44
		Industrial Products	94	30	10	50	5	10
		Food Products	151	95	4	1	0	0
		Lighter Fluids	252	0	0	0	0	100
U.K.	1976	Personal Products	242	22	42	35	1	0
		Household Products	243	21	78	1	0	0
		Industrial Products	13	58	7	20	15	0
		Lighter Refills	22	0	0	0	0	100
U.S.A.	1981	Antiperspirant	180	0	0	0	2	98
		Personal Deod.	55	0	0	0	0	100
		Hair Sprays	252	0	0	0	4	96
		Other Personal Products	260	74	1	2	0	23
		Household Products	1,090	23	20	4	1	52
		Industrial Products	177	10	2	1	2	85
		Food Products	147	71	0	5	1	23
		Lighter Fluids	280	0	0	0	0	100
U.K. (Est.)	1981	Personal Products	207	10	30	40	7	13
		Household Products	232	23	59	10	4	4
		Industrial Products	19	49	6	21	14	10
		Lighter Refills	27	0	0	0	0	100

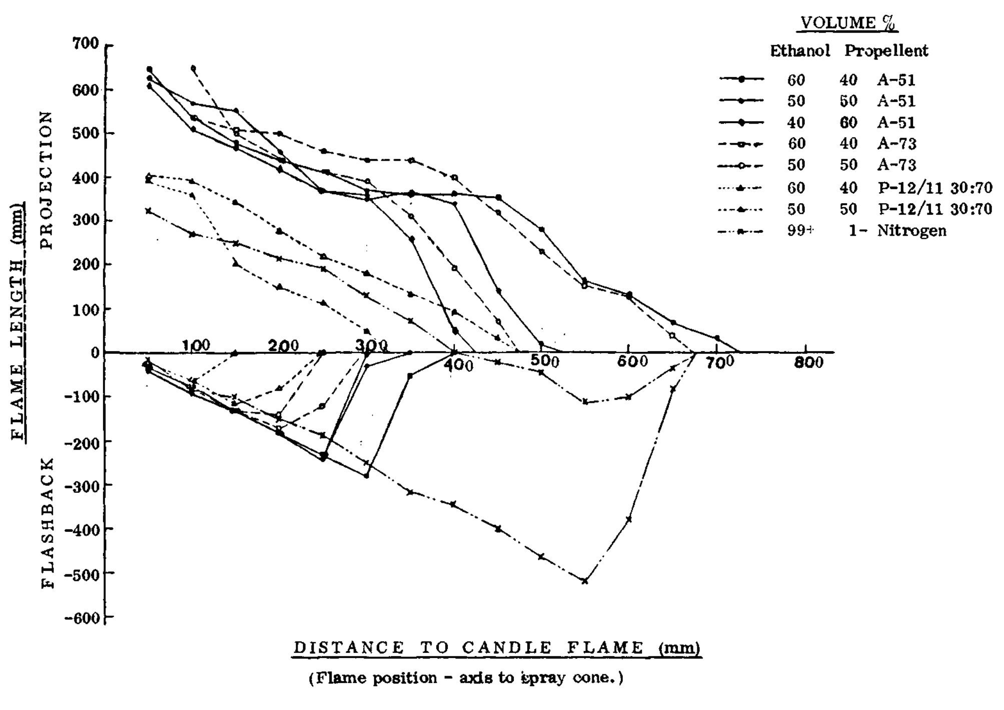
flammable hazard, and now they have done this as well. Aerosols have "Flammable Contents" (as before) if they contain 45% by weight or more than 250 g of substances having a closed cup flashpoint of 212°F (100°C) or less. In a later regulation (the Highly Flammable Liquids and Liquefied Petroleum Gases Regulations of 1972, S.I. 1972/917 aerosols with a total content of 500 ml or more and with a highly flammable content of more than 45% by weight or more than 250 g are regarded as having "Highly Flammable Contents". Highly flammable ingredients are here defined as either liquefied flammable gases or liquids having a flash point of less than 90°F (32°C).

During about 1978 Flammability Committees were formed within the FEA, BAMA and other associations for the purpose of developing various test methods, including counterparts of the Flame Projection Test and Closed Drum Test as used in the U.S.A. Modifications of these tests were considered also. One involved a determination of maximum ignition distance, by bringing a lighted candle progressively closer to the dispenser and actuating the valve until ignition occurred. Figure 1 provides the results of testing a variety of ethanol/propellent hair spray prototypes by this method. The delivery rate is assumed to be about 0.4 g/sec at 77° (25°C). The coarser sprays were the most flammable, according to the test results.

Other approaches involved a calculation of the weighted average heat of combustion in BTU/kcal/g) for the contents of filled cans, and a method for determining the relative flammability of a sprayed surface. Combinations of flammability methods have also been suggested. Perhaps the most notable in Europe was that presented by Vitat, Viel and Pichard of Rhone Poulenc Industries — France — at the FEA meeting in Brussels, March 26, 1980. It involved the use of four tests (%flammables content, flame extension, lower flammability limit and flashpoint/firepoint) to develop twenty numerical results per product. By complex statistical methods, involving principal components factor analysis, discriminant factor analysis and multivariate regression, products can be assigned a flammability index number from 0 to 100. The high flammability range extends from 71 to over 100. The FEA committees have not acted on the proposal during the two years since it was first presented, perhaps due to the complexity of the statistical treatment.

Figure 1. Flame Consequences of Spraying

Diagram illustrating flame consequences of spraying hair sprays various distances to a candle ignition source. Chart through the courtesy of the Aerosol Industry Association of Japan.



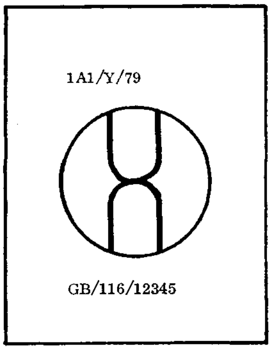


Figure 2.
UN Certification Marking
Explanatory Notes:
1A1 UN package number
Y Suitable for Group II and III (Medium and Minor danger)
79 Year of Manufacture
GB Made in Great Britain
116 Identification number of testing laboratory
12345 Test serial number

The standard European method for flame projection involves the use of a sophisticated tester developed in 1965 by Dr. Willi Roth of Switzerland. The effective flame length is established by mounting vertical cotton threads 10 to 20 mm apart, down the path of the aerosol flame plume. The last cotton thread to burn in two indicates the effective flame length. Since the equipment is quite costly and correspondingly unavailable to most laboratories, testers more like those in the U.S.A. have been used, with flame length measured visually against a rule.

There has been some discussion about modifying the basic flame projection test so that cans would be sprayed at the candle flame from various positions (upright, inverted and side) and from various distances. The testing of full, half-full and essentially empty cans was also suggested, as well as the use of various temperatures. It was felt that such added complexities, while they might more closely relate to the divergencies of consumer use, would increase the testing time perhaps tenfold. If the most flammable results were used as the basis for definition, then the expanded test could have the negative effect of making more aerosol products flammable than would be the case with the regular procedure.

The results of 4 to 6 laboratories were used to compile the data in Table III, which shows the results of flammability testing of various European aerosol cosmetics.

Aerosol Flammability Recommendations by the UN

In general, the recommendations by the United Nations (UN) are in close harmony with those of various international conventions, such as RID, ADR,

TABLE III

Typical Flammability Test Results - Europe
(Flame Projection and Closed Drum Test Methods)

				Flame Projection Test*			Closed Drum Test*		%-Flammable	
Test Product	Pressure; (psig; 68°F)	Spray Rate (g/sec - 68°F)	Density (g/ml)	Shortest	Longest	Flashback	Testers who had ignition.	Ignition time(s)	%(w/w)	%(v/v)
Hair spray using dimethyl ether	29	0.7	0.972	7"	14"	1"	60%	51 to 70	45	66
Hair spray using chlorofluorocarbon	41	1.0	1.04	7"	9"	2"	40%	50 to 51	38	—
Hair spray using butane/propane/CFC	35	0.8	0.912	6"	9"	0 to 6"	67%	31 to 78	—	—
Hair spray using carbon dioxide	88	0.65	0.995	10"	13"	0 to 3"	50%	42 to 56	42	—
Hair spray using methylene chloride and butane/propane	40	0.60	0.768	13"	19"	2 to 6"	100%	26 to 60	43	—
Personal deodorant using dimethyl ether	58	0.6	0.791	2"	6"	—	60%	54 to 81	65	79
Personal deodorant using chlorofluorocar.	19	0.6	0.951	5"	9"	0 to 6"	25%	83	57	—
Personal deodorant using butane/propane and chlorofluorocarbon	45	0.5	0.786	6"	11"	0 to 2"	60%	34 to 57	70	—

*Testers used various drum closures. The slit polyethylene closure gave fastest results.
**Bunsen burners, candles and a spark device were used as ignition sources. All gave equivalent results.

Courtesy: FEA (CTA Flammability Committee), 1981.

IMCO and IATA. Flammable aerosols are in Classes 2, 3 and 9, as in the IMDG code. They must carry the now familiar 100 mm × 100 mm red, diamond-shaped "flame" label on the outer shipper and meet package performance tests, such as drop, stacking and leakage tests. "Permitted packages" may carry the UN certification mark shown in Figure 2 along with required specific data.

Aerosol Flammability Regulations in Australia

Voluntary standards for aerosols are provided in Australian Standard AS 2278-1979 and are the same for non-flammable, flammable and highly flammable formulations:

a. Containers must have at least 10v% head space at 131°F (55°C) and must not become liquid filled at less than 185°F (85°C).
b. Maximum allowable pressures are as follows:
    i. Low pressure container: 140.7 psig at 131°F (970 kPa at 55°C).
    ii. Intermediate presssure container: 159.5 psig at 131°F (1.100 MPa at 55°C).
    iii. High pressure container: 179.8 psig at 131°F(1.240 MPa at 55°C).
    iv. Soldered side seam container: 100.0 psig at 100.4°F (690 kPa at 38°C).
    v. Tire inflator products at 185°F (85°) must not exceed the bursting pressure of the container.
c. All containers must be hot-tanked unless the contents are adversely affected.

The sole measure of flammability is the Flame Extension Test; AS 2278-1979 Section 2.4.3(a & b). Using an apparatus similar to that in Figure 3, aerosols are defined as "Flammable" if the average length of the flame is between 7.87-17.72" (200-450 mm) and "Highly Flammable" if the average length of the flame is over 17.72" (450 mm), or if it burns back to the actuator, or if it continues to burn when the test flame is extinguished.

Aside from relevant statutory requirements, where appropriate, each aerosol container must be prominently marked "Flammable" or "Highly Flammable" and must carry the appropriate symbol as specified in AS 1216 Part 1.

While the Australian Standard is not mandatory, the State of New South Wales has passed legislation where the Flame Extension Test is used to determine flammability, which in turn legislates specific labeling. The commercial importance of the State has thus, in effect, created a regulation for almost all products made in Australia.

With the dramatic increase in the use of hydrocarbon propellents in recent years, the industry has been talking with the authorities about potential problems in the storage and transport areas, and the use of definitions in the International Maritime Dangerous Goods (IMDG) code are being considered for outer shipper designations and handling procedures.

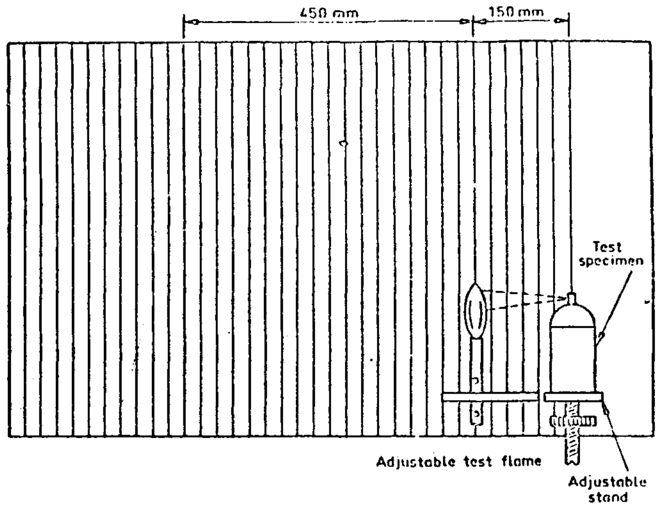
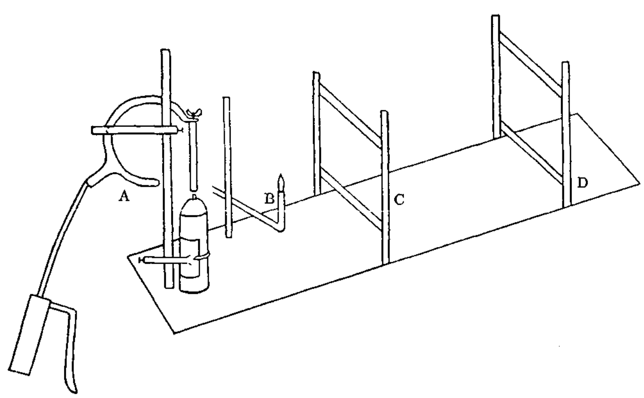


Figure 3. Australian Flame Projection Test Unit

Figure 4. Canadian Flame Projection Tester
A. Recommended remote can actuating device
B. n-Butane gas flame: 150 mm from actuator button
C. First frame for cheesecloth: 150 mm from flame
D. Second frame for cheesecloth: 450 mm from flame



Aerosol Flammability Regulations in Canada

In general, the aerosol regulations and industry accords in Canada are quite similar to those in the U.S.A., but this does not extend to flammability. During early 1979 a new modification of the Flame Projection Test was agreed upon between government officials and an industry committee containing representatives of the Canadian Cosmetic, Toiletry and Fragrance Association (CCTFA), Canadian Manufacturers of Chemical Specialities Association (CMCSA) and the Canadian Paint Manufacturers Association (CPMA). The apparatus is illustrated in Figure 4.

The device carries a holder to fix the aerosol can and spray, plus a recommended remote actuator, such as a caliper type, side pull bicycle hand brake. A burner tube with 0.050" (1.2 mm) gas orifice is positioned to terminate 2" (50 mm) below the aerosol orifice and is then adjusted to give a 2" (50 mm) flame height. If ignition fails to occur, the position is changed to 4" (100 mm) below the dispenser orifice and the flame adjusted to give a 4.7" (120 mm) height.

The burner is located 6" (150 mm) from the orifice of the dispenser. It is attached to a supply of n-butane via a regulator which governs the flame height.

Two vertically adjustable support frames are positioned 6" (150 mm) and 18" (450 mm) from the burner. They each have an open space 13.78" (350 mm) wide by 17.71" (450 mm) high. During the test they are used to support cheesecloth fabric, which is clipped on and drawn tightly across the open spaces.

The test is conducted by equilibrating three identical dispensers to 71.6 ± 3.8°F (22 ± 2°C). They are shaken and given a 5 second discharge to clear the dip tube of possible propellent. After fixing the first can in the stand, the flame is lit and a trial flame projection is made to see if the second flame position and height are to be required for combustion. Assuming a flame projection is achieved with at least one of the flame settings, the nearest open frame is fitted with cheesecloth and the aerosol is then sprayed at it, through the flame, for 5 seconds. If the cloth burns the test is repeated using the second frame. Any flashback to the container is noted, as well as any lack of flame projection. The remaining two units are then tested. The longest flame projection that causes burning of the cheesecloth is the one considered for labeling purposes.

The labeling consequences of the flame projection test are shown in Table IV. The text is bilingual (English and French) since this is a general labeling requirement for all Canadian products.

The industry is not particulary pleased with the labeling regulation, which went into effect in 1982. They accepted the test and definitions because the Federal Department for Consumer and Corporate Affairs was considering the use of a combination of the Flame Projection Test, Closed Drum Test, Modified Tagliabue Open Cup Flash Point Test and 45% Flammables Assessment as an alternate approach. The concept of calling an aerosol "Flammable" (triangle symbol) if there is any flame elongation whatever seems unduly harsh. With the continuing decline of CFCs in Canada, the test will have the effect of pronouncing as "Flammable" virtually all products that do not contain very large quantities of water, methylene chloride or 1,1,1-trichloroethane.

Tests using large numbers of cans have shown about a ± 6% variation in actual flame length for the same can, about ± 12% for different cans of the same product, and ± 20% for different cans (with vapor-tap valves) of the same product. These findings are matched by results obtained in BAMA (England) and CSMA testing programs. Considering this, there is an industry feeling in Canada that about 10% should be added to the average flame length of the three test cans. Thus, an average result of 16" (406 mm) would probably be adjusted to a maximum result of 17.6" (447 mm), which would cause burning of the cheesecloth positioned at the 17.7" (450 mm) distance. The product would then be considered "Extremely Flammable".

TABLE IV

Required Aerosol Labeling as a Result of Flame Projection Test

Flame Projection/ Longueur de la flamme	Symbol/ Symbole	Signal Word/ Mot-indicateur	Nature of Primary Hazard/ Nature de risque primaire
Less than 15 cm/ moins de 15 cm		Caution/ Attention	Flammable/ Inflammable
15 cm or more but less than 45 cm/ 15 cm et plus mais moins de 45 cm		Warning/ Avertissement	Flammable/ Inflammable
45 cm or more/ 45 cm et plus		Danger/ Danger	Extremely flammable/ Extrêmement inflammable
Flashback to the container/ Retour de flamme jusqu'au contenant		Danger/ Danger	Extremely flammable/ Extrêmement inflammable

Aerosol Flammability Regulations in Argentina

Argentina and several other Latin American countries have adopted the CSMA Flame Projection Test method as their criterion for the determination of aerosol flammability. Under Resolution No. 710 of Law No. 19,982, the Secretary of State, Commerce and International Economic Negotiations published IRAM Regulation No. 3793 (Oct. 3, 1978) to establish flammability labeling of aerosol products in Argentina. The testing device is essentially identical to that in use in the U.S.A., described in detail later in this chapter. The regulation covers all aerosols of capacity greater than 100 ml, except that for unprotected glass containers the pressure may not exceed 14.3 psig (1.00 kg/cm² or 98.6 kPa).

According to the results of the Flame Projection Test, aerosols are classified as follows:

a. Class A. If the flame extension is greater than 17.7″ (450 mm) or shows a flashback to the dispenser, the label must state, "Inflammable, do not spray over flame."

b. Class B. If the flame extension is from 7.9″ to 17.7″ (200 to 450 mm), the label must state, "Combustible, do not spray over flame."

c. Class C. If the flame extension is 7.9″ (200 mm), the label must state, "Do not spray over flame."

Figure 5. U.S.A. Flame Projection Testing Device

Components:

Heavy-duty poly-ethylene support base, about 8″ × 36″ × 2″ (200 × 915 × 51 mm)

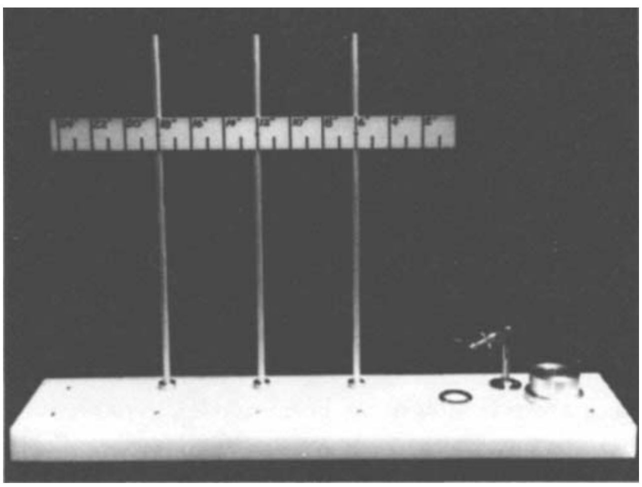
Three 15/32″ (12 mm) aluminum support rods for rule, preferably covered with ½″ (12,7 mm) i.d. Teflon tubing to prevent corrosion

Clear epoxy-coated heavy aluminum stick-ruler, marked to 24″ in 1″ increments

Metal centering ring for candle or gas burner

Adjustable-arm candle clamp, mounted on 6″ (150 mm) support rod

Container support base and positioner, adjustable in height



Other labeling, required for both flammable and non-flammable aerosols, includes the phrases: "Do not expose to temperatures greater than 50°C. Do not throw into fire or incinerator. Do not puncture. Refilling is prohibited." Labels must also indicate the brand and name of the merchandiser. Products are to be marked with the net contents in terms of grams and/or volume in cubic centimeters.

In the special case of cosmetic products, they may be pressurized with either carbon dioxide or CFC propellents, or CFCs mixed with hydrocarbons provided the flame projection is not over 7.9″ (200 mm). They are not permitted to use hydrocarbon propellents, exclusively. Because of economics, there has been a strong tendency to use propellents that are rich in butane (or even exclusively butane), and the Ministry of Public Health has had to monitor filling plants very closely to enforce this difficult law.

U.S.A. Flame Projection Test

The test apparatus in use today is still the same as that approved originally by the CSMA in 1951 and inserted into the Interstate Commerce Commission tariff in 1952. A rather elegant model, developed by the author, is shown in Figure 5, as well as the CSMA *Aerosol Guide* (Seventh Edition; April 1981) and other publications.

Tester designs vary widely. Every laboratory will normally build their own equipment. Since the hot flame plume curves upward, the horizontal ruler should be placed at least 6″ (150 mm) above the dispenser actuator. (See Page 485 for exact method.)

Testing should be done in a draft free area that can be ventilated and cleared of fumes after each test. Large amounts of product should not be sprayed in small, confined areas. If the formulation contains chlorinated hydrocarbons or CFCs, any burning of the spray will act to form toxic materials, such as formic acid, hydrochloric acid, hydrofluoric acid and traces of phosgene. Operators should then vacate the testing area immediately after completing each test, allowing it to be ventilated. Nasal irritation, along with possible headache, nausea and diarrhea, may result from excessive exposure.

The flame projection test is conducted as follows:

a. Equilibrate the dispenser to 70 ± 1°F (21 ± 0.5°C) in a water bath.
b. Shake the dispenser and spray briefly to clear any layered phases from the dip tube. Hold upright in the tester unless the labeled directions anticipate inverted use.
c. The dispenser is actuated by hand (or with a rod) so that the spray passes through the top third of the flame, located 6 ″ (150 mm) away. The button is fully depressed for 4 seconds, during which a second operator notes any extension of the flame and any flashback.
d. The test is repeated twice more with the same dispenser.
e. The flame projection and/or flashback figures are averaged for reporting purposes.

This procedure is equivalent to the one in the *CSMA Aerosol Guide* and *ASTM Standards*. It represents the best thinking of the aerosol industry. It is extremely unfortunate that the Federal Hazardous Substances Act regulations, developed by the FDA in 1960, contain an elaboration of this procedure to add the concept of ''flashback (a flame extending back to the dispenser) at any degree of valve opening''. The regulations were transferred to the CPSC in 1973 and the flashback definition was copied by the EPA about 1975 in the interest of regulatory harmony. To fully comply with the current regulations for CPSC and EPA products, the industry procedure must be extended by either spraying the product into the top third of the flame while slowly releasing the button to choke off the spray, or by aiming the product at the top third of the flame while slowly depressing the button to cause a gradual increase in spray rate. This aspect of the test has no pragmatic significance whatever. It was added by two FDA technicians who knew very little about aerosols, and who wanted to prevent persons having the end of their index finger burned if the spray accidentally caught fire. In reality, it is extremely hard to operate an aerosol valve in anything other than a wide-open position. If the spray did indeed catch fire, only in the rarest of instances would the flashback reach fully back to and touch the button at full actuation. One low-pressure cologne was shown to do this in some instances. The development of a flashback is a relatively slow process; it takes a second or two for the flame to fight its way back against the forward velocity of the spray. This would give the user plenty of time to release the actuator, causing a complete and immediate extinction of the spray and flame.

The gross effects of throttling off the spray are to increase particle size, lower the delivery rate and (most importantly) reduce the forward velocity of the spray. Depending upon the valve system, most aerosol sprays emerge from the actuator at forward speeds ranging from 10 to 32 ft/sec (3.05 to 9.75 m/sec). After the first 1 ″ (25 mm) of travel, the velocity is reduced by about 25%, due to break-up and air friction. The break-up introduces a widening range of velocities, since the explosion of a large initial particle into a host of smaller ones has vectors in all directions, including both forward and backward motions. The burning velocity of propane gas in air is 10.6 ft/sec (3.23 m/sec) and that of the butanes is about 9.3 ft/sec (2.83 m/sec) at ambient temperatures. The degree to which flashback extends toward the dispenser depends upon where the forward average velocity of the spray equals the backward burning (flame front) velocity of the flammable gases. (Note: only gases burn; not liquids or solids, which ignite only to the extent that they can form vapors.) At full actuation of a very flammable product the flashback will extend from 3.0 to 4.5 ″ (76 to 114 mm) toward the dispenser — almost always missing the actuator by at least 1.5 ″ (38 mm).

When the aerosol spray is deliberately throttled, the situation becomes quite different. The forward motion of the spray is reduced dramatically, and this quite often allows the flame to return to (and touch) the actuator if the spray is ignited. Again though, the return is slow enough that the user has ample time to release the button or even drop the aerosol, thus positively shutting off both spray and flame within a split second. Should the operator deliberately keep operating the dispenser in this unique, partly throttled fashion, then the flame may reach the sprayhead. For many products, particularly ethanol types, the button will have become wetted with product around the terminal orifice, so that when the flashback flame touches it the concentrate will ignite to produce a small candle-like flame perhaps 1.3 ″ (33 mm) high. This secondary flame will only last a second or two, but it will cause a heat blister on the finger of the operator.

The profoundly critical effect of the ''flashback...at any degree of valve opening'' has been illustrated by specific tests with 23 non-CFC and 3 CFC type aerosols representing commercial type formulations (see Table V).

TABLE V

Aerosol Flammability Test Results at Full Percentages of Full Delivery Rate

Product Type	General Formula		Valve Description	Flame Projection/Flashback 100% D.R.	50% D.R.	25% D.R.	Test Result*
Personal Deodorant	Actives Alcohol n-Butane CO_2	0.93% 76.07% 18.00% 5.00%	Precision 0.013" stem 0.060" body 0.017" capillary 0.016" Delta Concave	16"/4"	10"/5"	5"/6"	Extremely Flammable
Personal Deodorant	Actives Alcohol Prop. A70	1.77% 61.23% 37.00%	Summit S-63 0.030" stem 0.088" body 0.016" Vapor-tap 0.009"/0.011" MB	10"/0"	8"/0"	6"/0"	Not Flammable
Disinfectant/ Deodorant	Actives Alcohol DX Water Prop. A46	0.88% 53.09% 26.03% 20.00%	Summit S-63 0.016" stem 0.022" body 0.016" MB button	13"/0"	6"/2"	2"/4"	Extremely Flammable**
Hair Spray	Actives Alcohol CH_2Cl_2 Prop. A70	1.94% 66.07% 12.00% 20.00%	Precision 0.013" stem 0.061" body 0.017" capillary 0.016" RT button	12"4"	10"/6"	6"/0"	Extremely Flammable
Hair Spray	Actives Alcohol CH_2Cl_2 Prop. A31	2.50% 55.00% 12.50% 30.00%	Summit S-63 0.016" stem 0.016" body 0.020" MB button	15"/3"	12"/6"	8"/0"	Extremely Flammable
Hair Spray	Actives Alcohol Prop. A46	3.30% 60.70% 36.00%	Precision 0.016" stem 0.025" body 0.013" Vapor-tap 0.013" RT button	15"/0"	12"/0"	4"/0"	Not Flammable
Hair Spray	Actives Alcohol CH_2Cl_2 Prop. A46	3.30% 59.70% 12.00% 25.00%	Precision 0.013" stem 0.080" body 0.013" RT button	20"/5"	16"/5"	12"/0"	Flammable
Hair Spray (Fluorocarbon)	Actives Alcohol CH_2Cl_2 P-11/12 Prop. A31	2.00% 58.00% 8.00% 32.00%	Precision 0.018" stem 0.013" body 0.018" Reverse taper	17"/4"	14"/0"	9"/0"	Not Flammable
Hair Spray (Fluorocarbon)	Actives Alcohol CH_2Cl_2 P-11/12 Prop. A31	1.60% 34.00% 9.00% 50.00% 5.40%	Precision 0.018" stem 0.013" body 0.018" Reverse taper	16"/2"	14"/0"	8"/0"	Not Flammable
Hair Spray (Fluorocarbon)	Actives Alcohol Prop. A	1.16% 43.84% 55.00%	Seaquist NS-31 0.016" stem 0.013" body 0.020" Reverse taper	19"/0"	18"/0"	10"/0"	Not Flammable

*As per the Federal H.S.A., used by the E.P.A. and C.P.S.C. (Not F.D.A.)
**6" flashback achieved at less than 1/4 delivery rates.

TABLE V - Continued

Product Type	General Formula		Valve Description	Flame Projection/Flashback 100% D.R.	50% D.R.	25% D.R.	Test Result*
Leaf Polish	Actives IPA CH_2Cl_2 iso-Pentane CO_2	2.30% 27.70% 30.00% 37.00% 3.00%	Seaquist NS-31 0.010" stem 0.011" body 0.015" button	20"/0"	11"/0"	3"/6"	Extremely Flammable
S.S. Cleaner	Surfactant Solvent Distillates Perf./Pres. DX Water Prop. A60	2.50% 2.00% 26.00% 1.30% 51.20% 15.00%	Seaquist NS-31 0.016" stem 0.018" body 0.016" Dynamist but.	12"/2"	12"/0"	6"/0"	Not Flammable
Shoe Shine	Actives IPA $CH_3{\cdot}CCl_3$ Prop. A108	10.2% 20.0% 46.8% 23.0%	Seaquist NS-31 0.011" stem 0.010" body 0.015" Reverse taper	11"/0"	6"/0"	3"/0"	Not Flammable
Insecticide	Actives Pet. Dist. Prop. A55	0.9% 79.1% 20.0%	Precision 0.018" stem 0.018" body 0.018" Reverse taper	20"/3"	13"/0"	6"/6"	Extremely Flammable
Roach & Ant Sp.	Actives Solvent Pet. Dist. CO_2	1.0% 7.5% 88.9% 2.6%	Seaquist NS-31 0.013" stem 0.013" body 0.018" actuator	24"/0"	20"/6"	12"/6"	Extremely Flammable
Hair Spray	Actives Alcohol Prop. A46	1.6% 58.4% 40.0%	Precision 2 × 0.020" stem 0.080" body 0.020" vapor-tap 0.020" actuator	24"/0"	14"/0"	7"/0"	Flammable
Hair Spray	Actives Alcohol CH_2Cl_2 Prop. A46	4.2% 53.8% 15.0% 27.0%	Ethyl Corp. PARC-39 0.016" stem 0.018" body 0.020" MBU RKN-62	24"/0"	12"/0"	6"/6"	Extremely Flammable
Developer	Actives Pet. Dist. Prop. A46	2.5% 37.5% 60.0%	Ethyl Corp. AR-74 0.016" Vapor-tap 0.040" Capillary 0.018" RAR-90 button	17"/0"	12"/0"	10"/0"	Not Flammable
Suntan Oil	Concentrate† Prop. A31	53.0% 47.0%	Seaquist NS-31 0.018" stem 0.018" body 0.013" Vapor-tap 0.018" actuator	20"/0"	15"/0"	3"/6"	Extremely Flammable
Hair Dressing	Actives IPM Alcohol Prop. A70	7.00% 6.60% 52.35% 34.00%	Summit S-63 0.016" stem 0.016" body 0.016" Vapor-tap 0.013" MB button	8"/0"	6"/0"	0"/0"	Not Flammable

†Largely mineral oil, plus cocoa butter, lanolin, screening agent, scent, etc.

TABLE V - Continued

Product Type	General Formula		Valve Description	Flame Projection/Flashback 100% D.R.	50% D.R.	25% D.R.	Test Result*
Silicone Lubricant	Actives	3.75%	Seaquist NS-31	14"/0"	11"/0"	8"/0"	Not Flammable
	Pet. Dist.	30.00%	0.011" stem				
	$CH_3{\cdot}CCl_3$	62.45%	0.010" body				
	CO_2	3.80%	0.016" Excel Dy.M.				
Antistatic Spray	Actives	1.70%	Precision	24"/0"	6"/2"	2"/0"	Flammable
	Mineral Sp.	35.00%	0.013" stem				
	CH_2Cl_2	58.30%	0.062" body				
	CO_2	5.00%	0.020" capillary				
			0.018" MB Concave				
Burn Spray	Concent.*	75.00%	Precision	22"/0"	12"/0"	6"/0"	Flammable
	$CH_3{\cdot}CCl_3$	5.00%	0.020" stem				
	Prop. A31	20.00%	0.080" body				
			0.016" MB-ST button				
Butter Spray	Actives	3.00%	Newman-Green	0"/0"	0"/0"	0"/0"	Not Flammable
	Soy Bean Oil	94.00%	R-70-118				
	CO_2	3.00%	160-20-73 Sprayhead				
Athlete's Foot	Actives	3.00%	Ethyl Corp. T-56	13"/0"	12"/0"	8"/6"	Extremely Flammable
	Ucon Fluid	5.00%	0.016" stem				
	Alcohol	20.00%	0.016" body				
	Prop. A31	72.00%	0.016" Vapor-tap				
			RK-23 button				
Suntan Oil Spray	Actives	1.00%	Seaquist NS-31	16"3"	14"/4"	6"/6"	Extremely Flammable
	Mineral Oil	12.12%	0.018" stem				
	Veg. Oils	50.00%	0.018" body				
	Prop. A40	36.88%	0.018" button				

*Mainly vegetable oil; plus 4% benzyl alcohol, 2% benzocaine, oxyquinoline and other items.

Hydrocarbon-propelled products found to be extremely flammable included hair sprays without vapor-tap valves, personal deodorants without vapor-tap valves, athlete's foot spray, disinfectant/deodorant spray, sun tan spray and a leaf polishing spray.

Hydrocarbon based antiperspirants (typically containing 72% isobutane) and colognes have not been included in Table V, but are recognized from other studies to be generally in the extremely flammable category, depending upon formula and (more importantly) valve selection.

It is important to reiterate that two tests must be failed if an aerosol formula is to be considered extremely flammable: the flashback portion of the Flame Projection Test, and the Modified Tagliabue Open Cup (TOC) test. For EPA products the concentrate must have a TOC flash point of 20°F (-6.7°C) or less; for CPSC products the entire aerosol formulation must have a TOC flashpoint of 20°F (-6.7°C) or less. FDA type products are not covered.

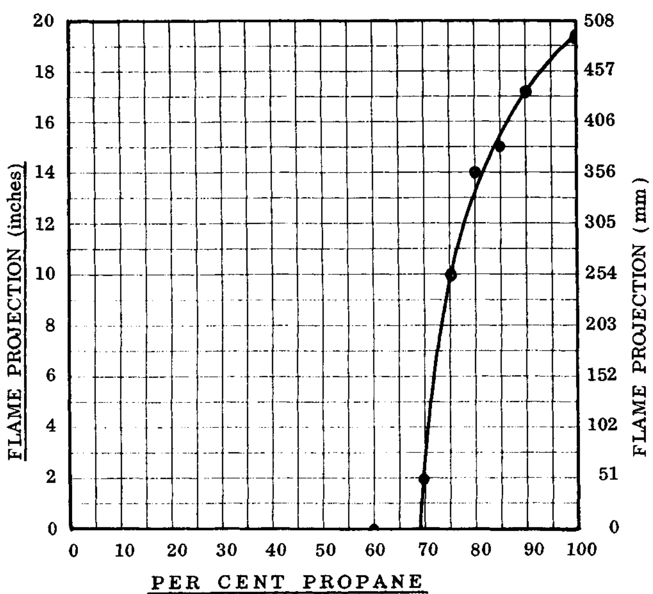
The Flame Projection Test is applicable to about 86% of all U.S.A. aerosol products. The principal exception is foam products, particularly shave creams and whipped creams, but other formulations such as pastes, lotions, pour-products, meter-sprays and so forth may also be impossible to test because they do not produce a sustained spray upon actuation. Products with a variable flow rate, such as the Newman-Green V-8 Series with Model 166 Series sprayhead, should be tested at the high/low or high/medium/low delivery rate choices, and the product should be labeled according to the most critical results encountered. Where extension tubes are used, the end of the tube should be positioned horizontally, 6" (152 mm) from the ignition flame. Tube lengths range from about 1" to 6" (25 to 152 mm) in the case of silicones, cleaning fluids and penetrating oil lubricants, on up to 30" (762 mm) in the case of a 99.2% methyl Cellosolve nitrosol pack used as a fuel additive for jet airplanes. If the product can be used with or without the extension tube, according to directions for use, then both dispensing modes should be tested.

The Flame Projection Test was designed as a consumer-oriented assay, bearing only a general relationship to storage and shipping considerations. It merely determines the ability of the spray to burn, without relevance to flashpoint, delivery rate, BTU content or other parameters. This can be easily illustrated. Methylene chloride has no flash point under ordinary atmospheric conditions, simply because it boils first — at 103.6°F (39.8°C). But when tested at supra-atmospheric pressures, such as those found in a mine, it displays a TOC flash point of 121°F (49.4°C). Despite the fact that it has a flashpoint under such conditions, it cannot be made to burn in the Flame Projection Test. In one experiment pure methylene chloride was heated in an aerosol can to 160°F (71.1°C), where it gave a pressure of 29 psig (200 kPa). Upon spraying, the dispenser produced an excellent spray pattern, but with no trace of flammability.

Propane was then added to methylene chloride in increasing amounts, checking for possible flame projection with the dispenser equilibrated to 70°F (21.1°C). At 70% propane occasional very short bursts of blue flame were produced. Longer flame projections were obtained as still higher levels of propane were tested. The data are illustrated in Figure 6.

Figure 6. Flame Projection Diagram

Chart illustrating flame projection of methylene chloride/propane mixtures. Temperature = 70°F (21°C). PVC valve, with 0.013" stem, 0.018" body, standard dip tube, Viton seat and cup gaskets and 0.016" MB-ST actuator.



The situation with isobutane and Halon 1301 (CF_3Br) is even more spectacular. As little as 5v% of Halon 1301 in air effectively prevents the hydrocarbon from burning, due to a unique free-radical reaction mechanism.

Methylene chloride has a heat of combustion amounting to 2,262 BTU/lb (126 kcal/100 g). The heat of combustion of a 67% propane and 33% methylene chloride solution is calculated as 15,231 BTU/lb (852 kcal/100 g). This is higher than ethanol, isopropanol and acetone, and on a par with diethyl ether. The fact that the mixture fails to burn in the Flame Projection Test shows that the test can be very insensitive to the BTU or caloric value of aerosol formulas.

Similarly, the test results are unaffected by the flash point of the aerosol composition. The non-flammable mixture of 67% propane and 33% methylene chloride has a flash point estimated at -142°F (-97°C), which is lower than at least 95% of all U.S.A. aerosol formulations. Conversely, the 100 psig (689.5 kPa) mixture of about 99.6% high-boiling USP mineral oil and nitrogen has a TOC flash point of typically 565°F (296°C) and can be made to cast a flame upwards of 20 feet (6.1 m) with the right valve. With standard taper valve buttons, however, flame projection may be zero. The similar mixture of USP mineral oil and 2.1% carbon dioxide will cast a very long flame with virtually any valve selection, merely due to the greater degree of break-up.

As mentioned earlier, valve design has a profound effect upon flame projection and flashback results. Reducing the delivery rate, by using a smaller inner orifice (stem orifice), will decrease flame projection considerably, but will have little effect upon flashback. Reducing the delivery rate by using a smaller tailpiece orifice will cause gas formation within the mixing chamber of the valve and cause both flame projection and flashback to dwindle accordingly. The use of a vapor-tap orifice has the dual effect of reducing delivery rate and bringing gas directly into the mixing chamber; thus this approach is effective in reducing both flame projection and flashback — often to zero, if the vapor-tap orifice is sufficiently large. The effect of reducing delivery rate by adjusting the inner orifice size, and by increasing the size of the vapor-tape from zero to 0.020" (0.51 mm) is shown in Table VI.

These results were obtained by using the same valve for each horizontal test series. A simple split toroid clamp (developed in Europe) is ideal for fixing the valve tightly down on the can bead without the necessity of crimping. At the end of a particular test the dispenser is emptied and the clamp loosened. Both valve and clamp are transferred to a new can containing the desired concentrate mixture. After tightening the clamp, T-t-V gassing is used to pressurize the dispenser with the correct amount of propellent. (See Figure 1, Page 283.)

By the use of the same valve, the inevitable delivery rate differences between valves can be avoided. These variations can often get to ± 15% and cause considerable pertubations in the results unless determinations on several individual cans are averaged. Large variations in product density, viscosity and pressure will affect delivery rate uniformity from a given specific valve. In some cases the effect of methylene chloride or other strong solvents will act to reduce delivery rate.

The data in Table VI show that vapor-tap valves can reduce flame projection of ethanol/hydrocarbon formulas down to less than 6 " (150 mm) and eliminate flashback entirely. In associated tests with a 0.023 " vapor-tap valve, both flame projection and flashback were eliminated. An extreme example is given in the literature, where 100% propane (as gas, at 70°F - or 21.1°C) exhibited a delivery rate of 1.08 g/s and failed to ignite in the flame projection tester. In the same sequence, 100% isobutane delivered at 0.34 g/s and also failed to ignite. The sprays could be used to extinguish the candle flame, as could that of P-152a gas.

TABLE VI

Flammability of Selected Hair Sprays by the Flame Projection Test

	Formulas and Test Results							
Ethanol (100%)	75%	60%	45%	40%	30%	15%	60%	25%
Methylene Chloride	—	15%	30%	35%	45%	60%	—	35%
Propellent A-46	25%	25%	25%	25%	25%	25%	40%	40%
At D.R. = 0.70 g/s								
Flame Projection (")	27.5	23.5	21.5	20.5	19.0	—	—	—
(mm)	700	597	546	521	483	—	—	—
Flashback* (")	6.0	6.0	6.0	6.0	3.0	—	—	—
(mm)	150	150	150	150	75	—	—	—
At D.R. = 0.45 g/s								
Flame Projection (")	23.0	22.0	20.0	17.0	15.0	7.0	22.5	20.0
(mm)	585	559	508	432	381	178	572	508
Flashback* (")	6.0	6.0	6.0	5.0	4.0	0.0	6.0	6.0
(mm)	150	150	150	127	102	0	150	150
At D.R. = 0.20 g/s								
Flame Projection (")	17.0	15.5	14.0	12.5	10.0	—	—	—
(mm)	432	394	356	318	254	—	—	—
Flashback* (")	6.0	6.0	6.0	6.0	5.0	—	—	—
(mm).	150	150	150	150	127	—	—	—
At D.R. = 0.45 g/s								
0.013 " Vapor-tap								
Flame Projection (")	—	—	—	—	—	—	20.5	16.0
(mm)	—	—	—	—	—	—	521	406
Flashback* (")	—	—	—	—	—	—	6.0	6.0
(mm)	—	—	—	—	—	—	150	150
0.016 " Vapor-tap								
Flame Projection (")	—	—	—	—	—	—	18.5	5.5
(mm)	—	—	—	—	—	—	470	140
Flashback* (")	—	—	—	—	—	—	6.0	0.0
(mm)	—	—	—	—	—	—	150	0
0.020 " Vapor-tap								
Flame Projection (")	—	—	—	—	—	—	5.5	2.5
(mm)	—	—	—	—	—	—	140	64
Flashback* (")	—	—	—	—	—	—	0.0	0.0
(mm)	—	—	—	—	—	—	0	0

*With valve in a fully opened position.

Particle size is another important parameter in the flame projection test. Fortunately, in the U.S.A. the test procedure anticipates the use of full cans. In other countries this is not always the case. For example, in the Swiss Official Methods aerosol dispensers having contents in excess of 50 g must be tested when full, 50% empty and 90% empty. Where the content is less than 50 g the test is conducted only at the 50% full level.

As a rule, the flame projection test results are made more critical by partially emptying the dispenser, since the spray normally becomes coarser and carries the flame further. The difference is particularly noticeable in the case of vapor-tap gradually becomes less effective due to the partial loss of propellent. Many vapor-tap systems use formulations that are typically 5% concentrate, 65% water and 30% hydrocarbon propellent.

TABLE VII

Flame Projection Test Results for an Insecticide

Formula: 67.5 to 77.5% (10 parts Isopropanol and Toxicants, plus 90 parts 1,1,1-Trichloroethane)
22.5 to 32.5% Hydrocarbon.

Valve: Summit Model SV-78, with stem, body and actuators as noted.
Temperature = 70°F (21°C).

Propellent Blend	%	Valve Stem	Valve Body	Valve Button	Pressure psig	kPa	Del. Rate (g/s)	Flam Proj. (in)		
A-46	30.0	0.020″	0.080″	AX-8359	30.0	207	2.60	>24	>24	>24
NP-52	30.0	0.020″	0.080″	AX-8359	33.0	228	2.46	>24	>24	>24
NP-52	32.5	0.020″	0.080″	AX-8359	35.0	241	2.50	>24	>24	>24
NP-52	32.5	0.020″	0.080″	0.040″ Ext.	35.0	241	2.67	>24	>24	>24
NP-65	22.5	0.020″	0.080″	AX-8359	38.0	262	2.52	32	30	35
NP-65	22.5	0.020″	0.080″	0.025″ Ext.	38.5	265	2.43	32	32	34
NP-65	22.5	0.020″	0.080″	0.023″ Str.	38.0	262	2.47	24	32	26
NP-65	25.0	0.020″	0.080″	AX-8359	39.0	269	2.66	0	0	>24
NP-65	25.0	0.020″	0.080″	AX-8359	43.0	296	2.89	0	>24	>24
NP-65	25.0	0.020″	0.080″	AX-8359	43.0	296	2.74	>24	0	>24
NP-65	25.0	0.024″	0.062″	AX-8359	44.0	303	2.80	32	32	30
NP-65	25.0	0.024″	0.062″	0.025″ Ext.	44.0	303	2.75	32	29	28
NP-65	25.0	0.024″	0.062″	0.023″ Ext.	44.0	303	2.58	32	33	30
NP-65	25.0	0.016″	0.062″	AX-8359	42.0	290	1.75	24	23	24
NP-65	25.0	0.016″	0.062″	0.025″ Ext.	42.0	290	1.79	0	24	24
NP-65	25.0	0.016″	0.062″	0.023″ Ext.	41.5	287	1.68	0	0	0
NP-65	27.5	0.020″	0.080″	AX-8359	41.0	283	2.65	>24	>24	>24
NP-80	22.5	0.020″	0.080″	AX-8359	45.0	310	3.01	26	29	24
NP-80	22.5	0.020″	0.080″	0.025″ Ext.	45.5	313	2.90	27	25	28
NP-80	22.5	0.020″	0.080″	0.023″ Ext.	45.0	310	3.11	0	24	0
NP-80	22.5	0.020″	0.080″	0.023″ Ext.	44.0	303	3.14	24	22	24
NP-80	22.5	0.016″	0.062″	AX-8359	47.5	328	3.36	22	26	24
NP-80	22.5	0.016″	0.062″	0.025″ Ext.	45.0	310	1.82	0	0	0
NP-80	22.5	0.020″	0.080″	0.025″ Ext.	44.0	303	—	24	24	0
NP-80	22.5	0.020″	0.080″	0.025″ Ext.	44.0	303	2.78	0	0	0
NP-80	22.5	0.020″	0.080″	0.023″ Ext.	44.0	303	2.59	0	24	24
A-108	22.5	0.016″	0.062″	AX-8359	61.5	424	2.60	0	0	0
A-108	22.5	0.016″	0.062″	0.025″ Ext.	61.5	424	2.00	0	0	0
A-108*	25.0	0.016″	0.062″	AX-8359	66.5	459	2.48	0	0	0
A-108	25.0	0.016″	0.062″	0.025″ Ext.	66.0	456	2.00	0	0	24
A-108	22.5	0.020″	0.080″	AX-8359	61.5	424	3.40	0	0	0
A-108	22.5	0.020″	0.080″	0.025″ Ext.	61.0	421	2.68	0	0	0
A-108	22.5	0.020″	0.080″	0.023″ Ext.	62.0	428	2.58	0	0	0
A-108	25.0	0.020″	0.080″	AX-8359	65.0	448	3.48	0	0	0
A-108**	25.0	0.020″	0.080″	0.025″ Ext.	64.5	445	2.70	0	0	0
A-108	25.0	0.020″	0.080″	0.023″ Ext.	65.5	451	2.60	0	0	0

*Best of group in terms of 0″ flame projection and good economics.

**Second best of group, same basis.

The initial fine mist of water serves to quench the potential flammability of the hydrocarbon — normally A-31, A-40 or A-46. But as propellent is progressively lost during operation of the dispenser, the water droplets become larger and less effective. At this point long bursts or gusts of blue flame will start to appear in the test, slowly changing to a steady flame as the unit is emptied still further.

The phenomenon of sporadic long spates of flame is not uncommon. It occurs where large percentages of flame suppressant substances are present in the formulation, such as water, methylene chloride or 1,1,1-trichloroethane. Outside the U.S.A. it is sometimes encountered with CFC formulations. Outstanding examples of sporadic, long-reach flaming can be found with the hydrocarbon/1,1,1-trichloroethane system, where the hydrocarbon is a high pressure type, used at about 25% of the total composition. Examples are shown in Table VII.

Flame projection is suppressed by lowering the delivery rate, but only to a slight degree. Reducing the concentration of the hydrocarbon propellent obviously is useful. But the best way to prevent occasional flaming is to decrease particle size by using (in this case) straight propane. Propane has significantly more break-up ability than the various blends of n-butane/propane shown in the table. In some of these tests there was no flaming for the full 4 second spray period, to be followed by a momentary 30" (762 mm) burst as the valve was released.

In conducting the test, flame bending should not be recorded so as to indicate a slight degree of flammability. Dispensers containing two separate liquid phases should be shaken just before each test. Otherwise, hydrocarbon type formulas will give falsely optimistic results. The dip tube should always be cleared before testing, or momentary long-reach flames might result from trapped or phase-separated hydrocarbon propellents in the tube. It is very important to keep test cans at the 70°F (21°C) temperature. If a constant temperature bath is not available in the testing area, the cans should be kept in an insulated bucket of 70°F (21°C) water before or between uses. The delivery rate should be recorded, for those cans tested. If the delivery rate of other cans of the same product is significantly higher, due to valve variation, air entrapment or other causes, the test should be repeated using the highest delivery rate can available. Some marketers use a test variation allowance of 1 to 2 inches (25 to 50 mm), which is added to the flame projection result found during product development. Others feel that 90 to 95.5% of the cans should fall within a flame projection range equal or less than the flame projection "maximum" value, recorded in product specifications.

Much criticism has been devoted to the shortcomings of the flame projection test. Despite the spectacular and simplistic nature, it has little pragmatic significance in terms of consumer hazard. Well over 90% of consumer fires are caused by product misuse, such as overheating the dispenser in or on a stove, in a backyard incinerator (sometimes called a "burn barrel") or in a place heated excessively by the sun. In other cases, dropping the container may act to cause valve leakage (frequency below 1%) if the cover is not in place. If the dispenser is already severely overpressurized, due to heating, dropping may cause it to burst.

Nearly all fires that are caused by actually spraying the aerosol are surface coating fires, where the application of the spray causes a hard or absorbant surface to become flammable. During pre-aerosol days, numerous fires were started by pump-sprayers (the old-fashioned "Flit gun") used to treat the tops of cast iron plate stoves with kerosone-based stove polishes or insecticides. The gas or coal fires often burning below the heavy ironplates might then cause the hot kerosone to flare up and severely burn the person doing the spraying. In a more modern setting, during the early 1970s a number of oven fires and "whoosh" types explosions were encountered in England after the introduction of aerosol oven cleaners, containing about 20% of a combustible organic solvent in addition to the 5% or so of isobutane propellent. After the foam layer broke and much of the water evaporated, the solvent vapors exceded the lower explosive limit (LEL) concentration in air, and when this mixture came into contact with the oven pilot light very rapid burning resulted. The British Aerosol Manufacturers Association (BAMA) reacted quickly. Their *Code of Practice* (Fourth Edition - 1980) now states that "Flammability hazard under in-use conditions shall be minimized by restricting the percentage of flammable contents to 6%w/w." The label also warns that the oven door should be kept open after spraying. Similar problems existed about 1972 in the U.S.A. and were recited by a consumerist group during the first formal hearing held by the newly created CPSC during that year, which happened to be on the subject of aerosol safety.

The glow from burning cigarettes or cigars is not sufficiently hot to ignite a potentially flammable aerosol spray — despite unsubstantiated reports that are received every five years or so, suggesting that the momentary, tiny fire on certain charring cigarette papers can cause sprays to ignite. As a result, the applicability of the flame projection test results in the real world would seem to be limited to the spraying of oven gas stove or hot water heater pilot lights. In one case, an insecticide containing 50% hydrocarbon propellent was claimed to have ignited the area under a gas-fired refrigerator when the spray contacted the pilot light. No reports have been seen regarding combustion from gas-fired floor furnaces or electrical resistance wire heaters.

The flame projection test remains as the most popular assay for aerosol flammability, despite its many shortcomings of both a technical and pragmatic nature. It is certainly to be preferred over other individual flammability tests, and also offers the development chemist the flexibility of adjusting products to pass the test by various alterations of formultion and valve design.

U.S.A. Closed Drum Test

This test is of little importance today, so coverage is correspondingly brief. It was developed concurrently with the Flame Projection Test in 1951 and made a part of the I.C.C. regulations during the following year. It is still in the latest interstate shipping tariff, but is applied only to those institutional or industrial products between 35 to 50 cu. in. (573.6 to 819.4 ml) for which there is no consumer counterpart product. Such products are extremely uncommon. A few other countries use the test; for instance, it is called the "barrel test" in the Swiss Official Methods manual and is used to assess

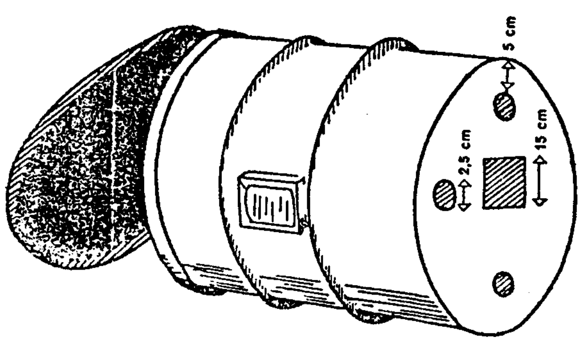


Figure 7. Closed Drum Test Apparatus
55 gallon or 200 liter size drum

the flammability of aerosols larger than 50 g of contents weight. An illustration of the Closed Drum Tester is given in Figure 17. (See Page 486 for exact test method.) A complete description of the tester is provided in the *CSMA Aerosol Guide* (Seventh Edition, April 1981), but briefly, it consists of a 55 (U.S.) gallon or 200 liter steel drum, laid on its side, with two 6"x6" (150x150mm) windows and either one (CSMA) or three (I.C.C., Switzerland, etc.) 1.00" (25.4mm) diameter ports in the solid end, as shown in the drawing. The single port used in the CSMA and ASTM procedures is located at the top of the solid end.

The other end is hinged to the drum body, or better, a sheet of either 0.0022" (0.05 mm) polyethylene or 0.0005" (0.013 mm) nylon film is stretched over the drum body and held in place with a very large rubber band or circular tension spring. A 1" (25 mm) diameter candle set in the center of the bottom is lit — with a long taper, through a port, if the end is plastic covered. Immediately start spraying the 70°F (21°C) test can through the top port. Record spray time at full actuation until the LEL is reached and a large scale burning and pressure "whoosh" take place. In the U.S.A. procedure, the test may be terminated at 60 s if no result is obtained. In the Swiss method at least 20 g must be sprayed into the drum without effect, if the dispenser is to be considered non-flammable. The interpretive parameters for the smaller Japanese Closed Drum test have already been mentioned.

Even though the test has practically no regulatory significance any more, aerosol chemists still use it to assess the flammability of certain products, particularly those where large amounts of the formulation are released at any one time. Examples include the indoor fogger, where the can is latched open and sprayed to emptiness, undercoating products and so forth. Some laboratories prefer to measure flammable potential of these products in terms of the number of cubic feet (or liters) that can be brought to a LEL by dispensing the entire can. In such cases, the cans will be sprayed until the drum flames and develops a pressure "whoosh", and the weight loss will then be determined. A simple calculation will then give the desired result.

A candle flame is probably the best ignition source, but it has the disadvantage of removing some of the oxygen in the drum and also pre-burning a portion of the aerosol contents. In some cases, the candle flame will increase to a height of 18" (457 mm) and touch the top surface of the drum, and still it may be a number of

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