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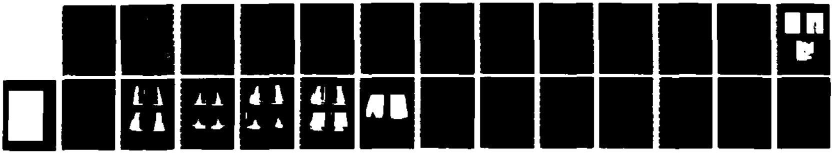

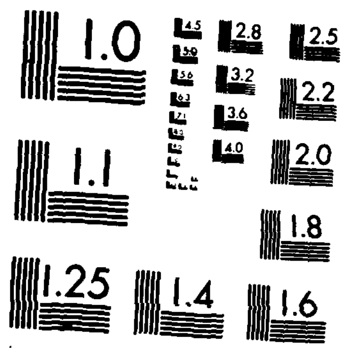

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AD-A173 860

An Investigation of the FAA Vertical Bunsen Burner Flammability Test Method

Patricia Cahill

August 1986

Final Report

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16. Abstract

The vertical Bunsen burner test method, as specified in appendix F of the Federal Aviation Regulations - Part 25, was evaluated in order to update and clarify certain problem areas. Burner fuel, flame temperature and flame placement were investigated. It was determined that (1) methane gas can be used as a replacement or alternative to B-gas, (2) a minimum flame temperature specification is meaningless without specifying thermocouple wire thickness, and (3) placing the flame at the midpoint of the lower edge of the front face results in a more realistic and severe evaluation of the specimen's flammability properties.

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EXECUTIVE SUMMARY

This report contains the results of an evaluation of the vertical Bunsen burner test method as specified in appendix F of the Federal Aviation Regulations (FAR) Part 25. Burner fuel, flame placement, and flame temperature were evaluated.

The currently used burner fuel, B-gas, was compared to methane gas. Test results show that burn length and flame time are similar for both gases when the gases are fresh. However, a chemical reaction occurs with aging in B-gas between carbon monoxide and the iron in the steel cylinder, making it difficult to consistently regulate flame height. This problem is eliminated with the use of methane gas.

Flame placement was evaluated for test specimens ranging up to 1 inch in thickness. It was found that placing the flame at the midpoint of the lower edge of the front face resulted in a more realistic and severe evaluation of the test specimen's flammability properties. This applies to all specimens regardless of thickness. With the exception of foam, burn results show that it is necessary to test both front and back faces of test specimens 1/2 inch and greater to ensure a realistic assessment of surface flammability.

Flame temperature experiments were carried out using various thermocouple gauge sizes. Test results show that an inverse relationship exist between flame temperature and thermocouple gauge size. Therefore, a minimum flame temperature specification is meaningless without specifying the thermocouple gauge size.

INTRODUCTION

PURPOSE.

The purpose of this report is to present the results of an investigation of the vertical Bunsen burner test method as specified in appendix F of the Federal Aviation Regulations (FAR) Part 25.

BACKGROUND.

In 1951, Federal Specification CCC-T-191b, "Textile Test Methods" was issued for government procurement purposes. It included a horizontal flammability test for cloth, Method 5906, and a vertical flammability test for cloth, Method 5902, whose general apparatus and procedures were eventually used in Federal Aviation Administration (FAA) regulations.

In 1967, Amendment 15 for FAR Part 25 was issued by the FAA. This Amendment did not reference the CCC-T-191b methods, but instead, documented the test procedure with reference to Method 5902 in appendix F of FAR 25.

In 1968, Federal Test Method Standard (FTMS) 191 replaced CCC-T-191b. Method 5903 replaced Method 5902 which was dropped at the time of this change. Method 5903 differed from Method 5902 in that it specified a particular gas mixture for use as burner fuel.

The vertical Bunsen burner test method has evolved into a certification and quality control flammability test for a wide variety of aircraft interior materials (honeycomb, composites, plastic sheets, foams, fiberglass insulation, etc). It has been proven to be an effective and convenient test procedure. Nonetheless, over the years, a number of problem areas have arisen, some traceable to the originial test procedure being intended for cloth materials, that create inconsistencies in data. This report presents an investigation of several of the most pertinent problem areas with the aim of producing a more clear and concise test procedure that will reduce the likelihood of ambiguous or inconsistent data.

DISCUSSION

BURNER FUEL.

Appendix F of FAR Part 25 specifies a particular gas mixture for use as Bunsen burner fuel by reference to FTMS-191 - Method 5903, "Flame Resistance of Cloth; Vertical." This specific gas mixture is commonly referred to as B-gas. However, it is sold by different trade names, depending on the gas producer. As an example, Matheson Gas Products call the gas mixture "Flame Resistance of Cloth Test Gas." Components of the gas mixture are specified as follows:

Hydrogen	55 ± 1%
Methane	24 ± 1%
Ethane	3 ± 1%
Carbon Monoxide	18 ± 1%

Many testing facilities have stated that B-gas produces inconsistent flame characteristics from cylinder to cylinder. Furthermore, this inconsistency is reflected in variable test results. Evaluation of the B-gas has verified that inconsistent flame characteristics do indeed exist from cylinder to cylinder. Figure 1, photographs a, b, and c, show actual B-gas flames from three different cylinders of various ages (age listed under each photograph). The characteristics of the three B-gas flames are vividly different. Photograph c shows an especially elongated and intensely orange-spiked flame while a double cone formation is shown in photograph b. Laboratory evaluation of both flames confirmed the presence of an iron oxide compound (Fe_2O_3) emanating from the flame. Fe_2O_3 is a product of the reaction:

$$2\,Fe(CO)_5 + 6\,O_2 \longrightarrow Fe_2O_3 + 9CO_2 + CO$$

Iron pentacarbonyl is a colorless to yellow oily liquid and is formed by the reaction of carbon monoxide (CO) with iron (Fe). The primary source of iron is the steel cylinder in which the B-gas is contained. In effect, what is seen in photograph c of figure 1 is the atomic spectrum of iron, while photograph b depicts an intermediate stage. As the cylinder ages, more iron pentacarbonyl is formed, ultimately resulting in the flame characteristic seen in photograph c. The formation of a spike or double cone in the burner flame makes it difficult to adjust the burner to give a flame of 1 1/2 inches in height as specified in appendix F of FAR, Part 25. More importantly, as the flame characteristics are altered with age, the intensity of the flame and the resulting material sample burn characteristics will also change.

Methane gas of 99 percent purity was tested as a substitute for B-gas. Referring to figure 2, note the well defined diffusion flame of the methane gas. The blue reaction zone can be seen on the outside of the luminous carbon zone, and reaches to the top of the flame. Flame height is well defined and easily regulated as a result of this well defined flame tip. In order to compare B-gas with methane, various materials were tested. Referring to table 1, it can be seen that burn lengths and flame times are very similar for both gases.

FLAME TEMPERATURE.

Appendix F of FAR, Part 25 requires that the minimum flame temperature in the center of the flame be at least 1550° F for the vertical burn test. This temperature minimum is also required for the horizontal and 45-degree tests. The 60-degree test specifies a minimum temperature of 1750° F in the hottest portion of the flame. A calibrated thermocouple pyrometer is specified for temperature measurement. However, no particular thermocouple gauge size is required.

A number of experiments, employing five different gauge size thermocouples, were performed in order to examine flame temperature in the center of the flame. Flame height (1 1/2 inches), gas delivery pressure (2 1/2 $\pm$ 1/4 pounds psi), and all other requirements were followed according to the rule. An in-line needle valve was used to regulate gas flow. The Bunsen burner base had a 1.5 mm orifice diameter. Other bases with orifice diameters as small as 0.67 mm were evaluated with no significant test result differences. However, the base with the 1.5 mm orifice produced a conical flame with complete flame impingement around the burner mouth and, therefore, was used in all testing. The thermocouples were inserted into the flame horizontally. For comparison, B-gas and methane flame temperatures were evaluated. From figure 3, it can be seen that flame temperature and thermocouple gauge size are inversely proportional to each other. The 36-gauge Chromel Alumel thermocouple reflects the highest average temperature for both gases while the lowest average temperature is seen with the 20-gauge thermocouple.

TABLE 1. VERTICAL BURN TEST RESULTS

SAMPLE	DESCRIPTION	Average of 3 Samples: Flame Time (sec) Methane	Flame Time (sec) B-gas	Burn Length (in.) Methane	Burn Length (in.) B-gas
Carpet	90/10 Wool Nylon Warp Dir.*	2.7	2.2	1.3	1.2
Carpet	90/10 Wool Nylon Weft Dir.*	2.4	1.9	1.2	1.2
Carpet	85/15 Wool Nylon Warp Dir.	6.1	7.0	2.4	2.7
Carpet	85/15 Wool Nylon Weft Dir.	3.6	4.0	2.1	2.3
Upholstery	90/10 Wool Nylon	1.0	0.7	2.1	1.6
Drapery	35/65 Wool Synthetic	0	0	3.3	2.7
Ceiling Panel	Tedlar Finish Epoxy/Fiberglass Facings Phenolic/Nomex Core	0	0	3.3	3.2
Sidewall Panel	Tedlar Finish Epoxy/Fiberglass Facings Phenolic/Nomex Core	0	0	3.4	3.8
Partition	Tedlar Finish Epoxy/Fiberglass Facings Phenolic/Nomex Core	0	0	1.9	1.6
Stowbin Shelf	Tedlar Finish Epoxy/Fiberglass Facings Phenolic/Nomex Core	0	0	1.5	1.1
Flooring	Carbon/Epoxy Facings Nomex/Phenolic Core	0	0	1.6	2.1

* Tested in warp direction - yarns extended lengthwise
* Tested in weft direction - crossing yarns

It is known that wire (in this case, thermocouple wire) will normally be cooler than the flame gases, owing to heat losses by radiation, conduction, and convection. Thus, as the thickness of the thermocouple wire is decreased, the closer the measurment to the real flame temperature. There is obviously a limit set by the mechanical strength of the wire for the smallest diameter thermocouple wire that can be practically utilized; therefore, nothing finer than 36-gauge wire was tested.

Referring to figure 3, both the B-gas and methane flames show an average temperature of 2300° F in the center of the flame when measured with the 36-gauge thermocouple. According to Hassian and Russel, theoretical flame temperature for methane exceeds 3000° F (reference 2), thus, the measurement was reasonable and, perhaps, still below the true flame temperature.

FLAME PLACEMENT.

According to appendix F of FAR Part 25, the flame for the vertical burn test must be applied to the center line of the lower edge of the specimen. This is an ambiguous statement since it does not specify a point, but a line.

While initially a cloth materials test, the vertical burn test now encompasses interior aircraft composite materials such as class partitions which can range over one inch in thickness. For this reason, flame placement must be clearly identified.

Interior ceiling panels, wall panels, cabinet walls, structural flooring, etc., are generally sandwich composites. The composites are fabricated by bonding resin systems such as epoxies or phenolics to a honeycomb core material with an adhesive. While core materials such as balsa, glass, and aluminum are used in certain applications, core material used in aircraft composite panels is primarily an aromatic polyamide sold under the trade name of Nomex™. Testing with the Bunsen burner has shown Nomex honeycomb core to be self-extinguishing.

At the present time, the burner is positioned under the geometric center of the bottom surface of the test specimen. This is common practice in most test facilities. However, testing has shown that placing the flame on the midpoint of the lower edge of the front face produces test results that best represent the specimen's overall flammability properties. Figures 4, 5, and 6 depict various panels of different thicknesses burnt with the flame placed in the geometric center of the bottom surface and also on the midpoint of the lower edge of the front face.

No distinguishable difference in burn length can be seen for the thin specimens shown in figure 4. However, the differences are obvious when viewing the thicker panels shown in figures 5 and 6. For samples 1/2 inch and greater, geometric center flame placement does not give test results representative of the material's total flamability properties. This is due to flame impingement primarily on the self-extinguishing honeycomb core.

Referring to figure 7, note the absence of flame impingement on the back face of the panel. While flame placement on the midpoint of the lower edge of the front face gives more realistic test results, it was found that it is necessary to test the back face as well for samples 1/2 inch and greater. One test specimen, however, may be used for both front and back face testing.

According to appendix F of FAR, Part 25 thick foam parts, such as seat cushions, must be tested in 1/2-inch thickness. Referring to figure 8, flame placement on the midpoint of the lower edge of the front face resulted in a melting away of the material. However, the burn length is the same as the sample with geometric center flame placement. For foam test specimens, it is not necessary to separately test front and back faces. Unlike composite materials or carpets with different backings, polyurethane foams are homogeneous.

SUMMARY OF RESULTS

1. Burn length and flame time values are similar for both B-gas and methane when used as burner fuel if the B-gas flame characteristics have not been altered by aging. It appears that the change in the flame characteristics of B-gas with aging is a result of chemical reactions with the iron in steel storage cylinders.

2. Flame height is much easier to regulate with methane as opposed to B-gas due to methane's reproducible flame characteristics.

3. Placing the flame on the midpoint of the lower edge of the front face of composite test specimens produces more realistic and severe test results than placing the flame in the geometric center of the bottom face.

4. With the exception of foam, flammability properties of test specimens 1/2 inch and greater in thickness are best represented by testing the back face in addition to the front face (one test specimen may be used for both tests).

5. An inverse relationship exists between the measured flame temperature and thermocouple gauge size.

CONCLUSIONS

1. Methane gas can be used as a replacement or alternative to B-gas as Bunsen burner fuel because it produces similar flame characteristics and does not experience an alteration in flame characteristics as a result of storage cylinder aging effects.

2. Placement of the burner flame at the geometric center of the specimens bottom edge does not give a realistic and severe assessment of surface flammability for composite materials.

3. With the exception of foam, all test specimens 1/2 inch and greater in thickness should be tested on both front and back faces in order to asses surface flammability.

4. A minimum temperature specification is unnecessary and meaningless without a thermocouple gauge size specified.

REFERENCES

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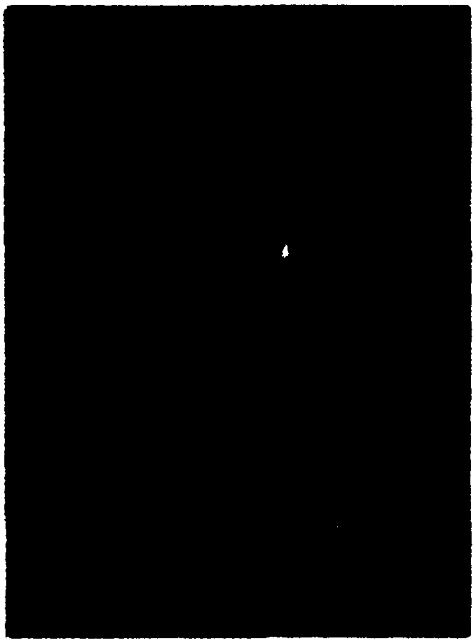
2. Hasian, R., and Russel, R., Fuels and Their Combustion, McGraw Hill, New York, 1929.



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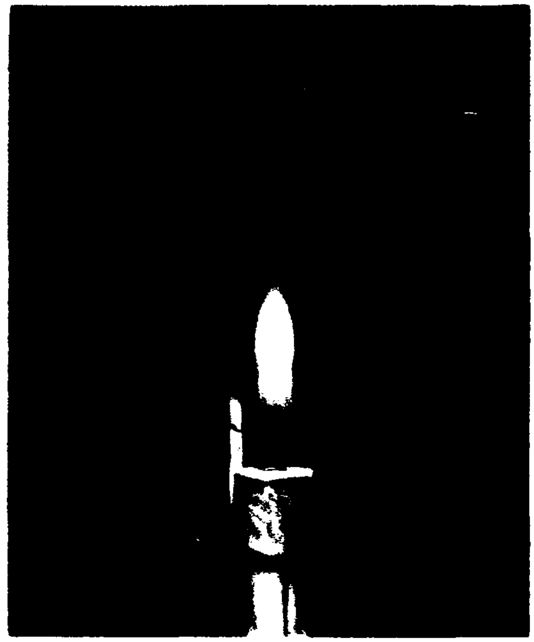
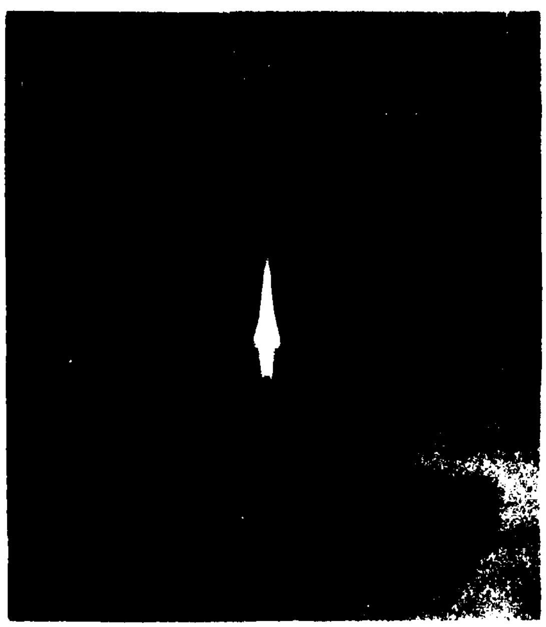
1 MONTH



B.
6 MONTHS



C.
18 MONTHS

FIGURE 1. B-GAS FLAMES

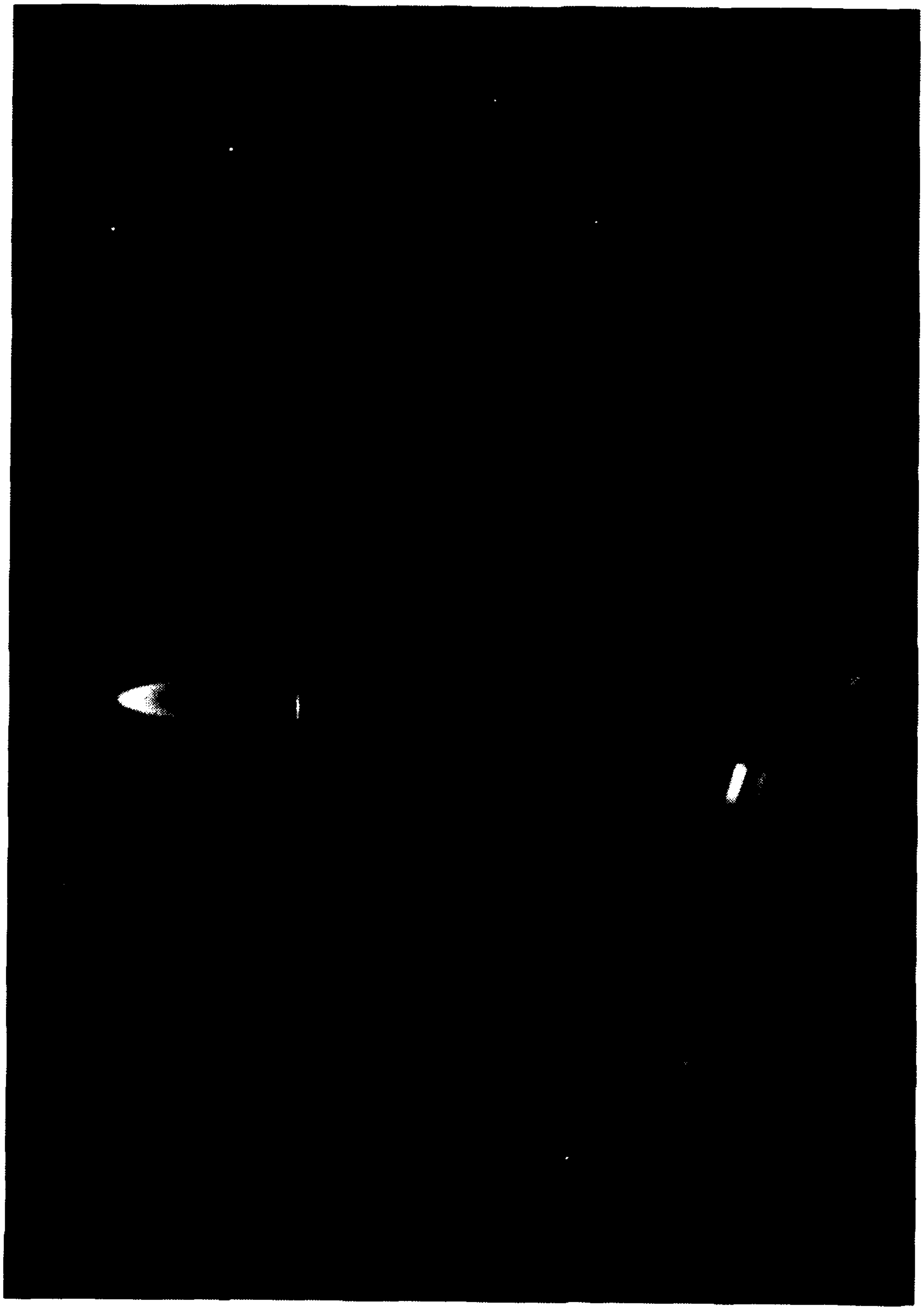


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FIGURE 2. METHANE GAS FLAMES

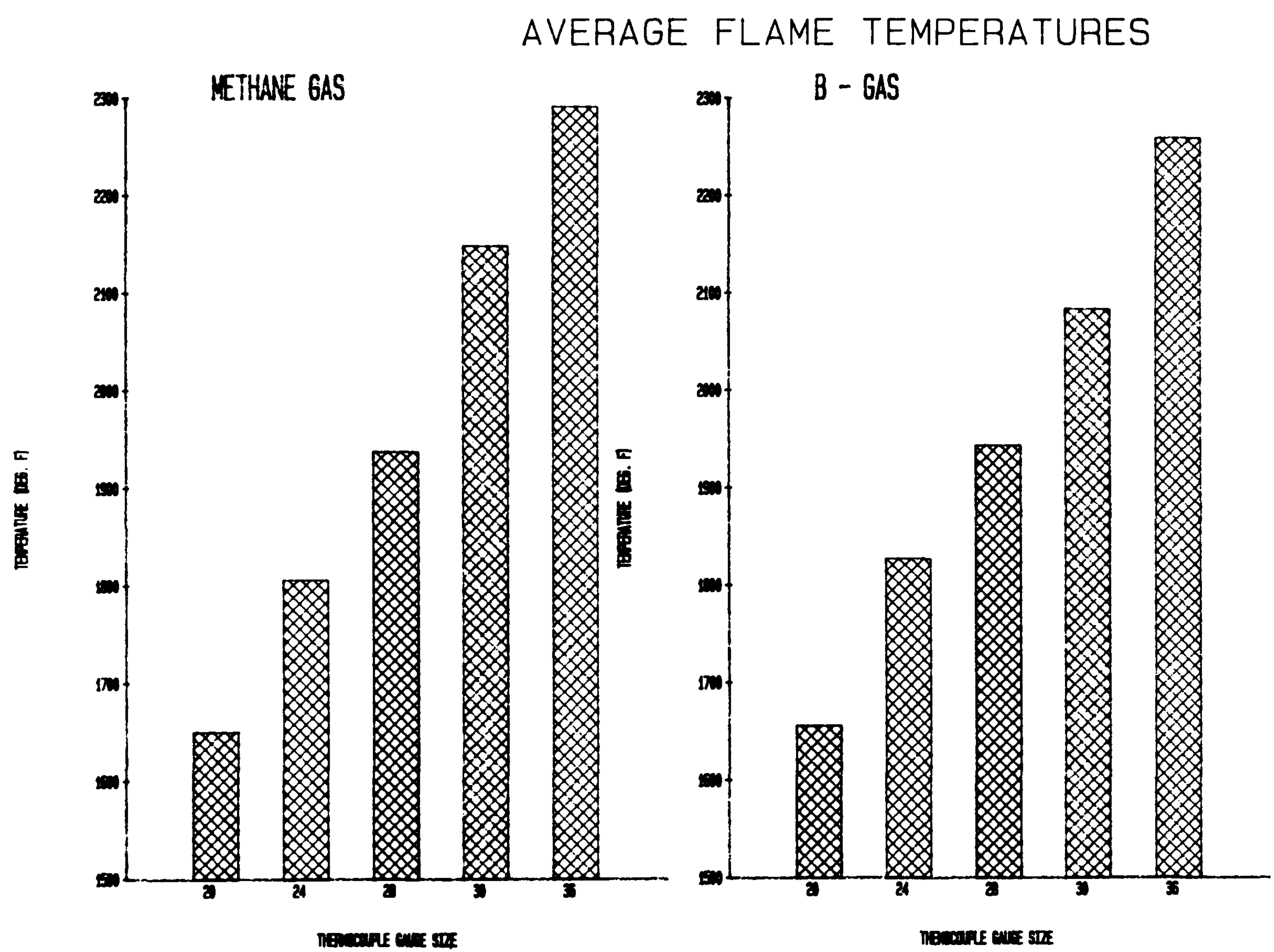


FIGURE 3. AVERAGE FLAME TEMPERATURES

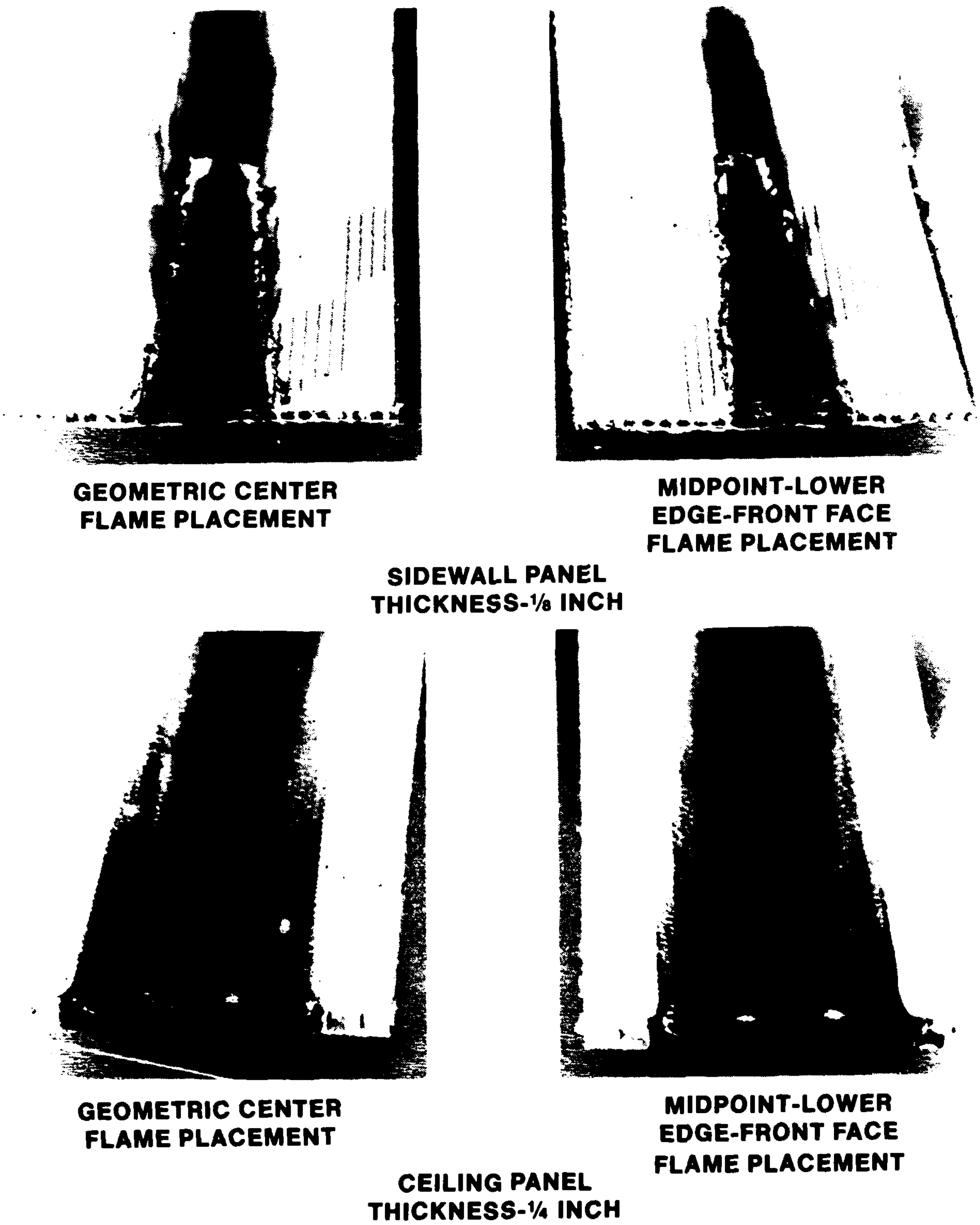


FIGURE 4. EFFECT OF FLAME PLACEMENT ON COMPOSITE BURN RESULTS (THICKNESS 1/8, 1/4 INCH)

GEOMETRIC CENTER
FLAME PLACEMENT

MIDPOINT-LOWER EDGE-
-FRONT FACE
FLAME PLACEMENT

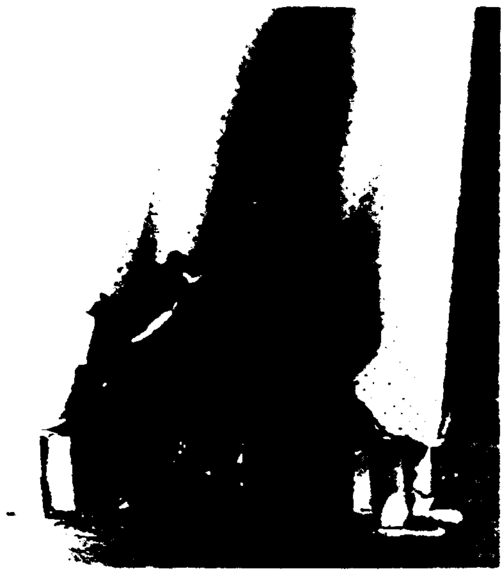
FLOORING
THICKNESS - ⅜ IN.

GEOMETRIC CENTER
FLAME PLACEMENT

MIDPOINT-LOWER EDGE-
-FRONT FACE
FLAME PLACEMENT

STOWBIN SHELF
THICKNESS - ½ IN.

FIGURE 5. EFFECT OF FLAME PLACEMENT ON COMPOSITE BURN RESULTS (THICKNESS 3/8, 1/2 INCH)



GEOMETRIC CENTER
FLAME PLACEMENT

MIDPOINT-LOWER
EDGE-FRONT FACE
FLAME PLACEMENT

CEILING PANEL
THICKNESS-¾IN.

GEOMETRIC CENTER
FLAME PLACEMENT

MIDPOINT-LOWER
EDGE-FRONT FACE
FLAME PLACEMENT

CEILING PANEL
THICKNESS-1 INCH

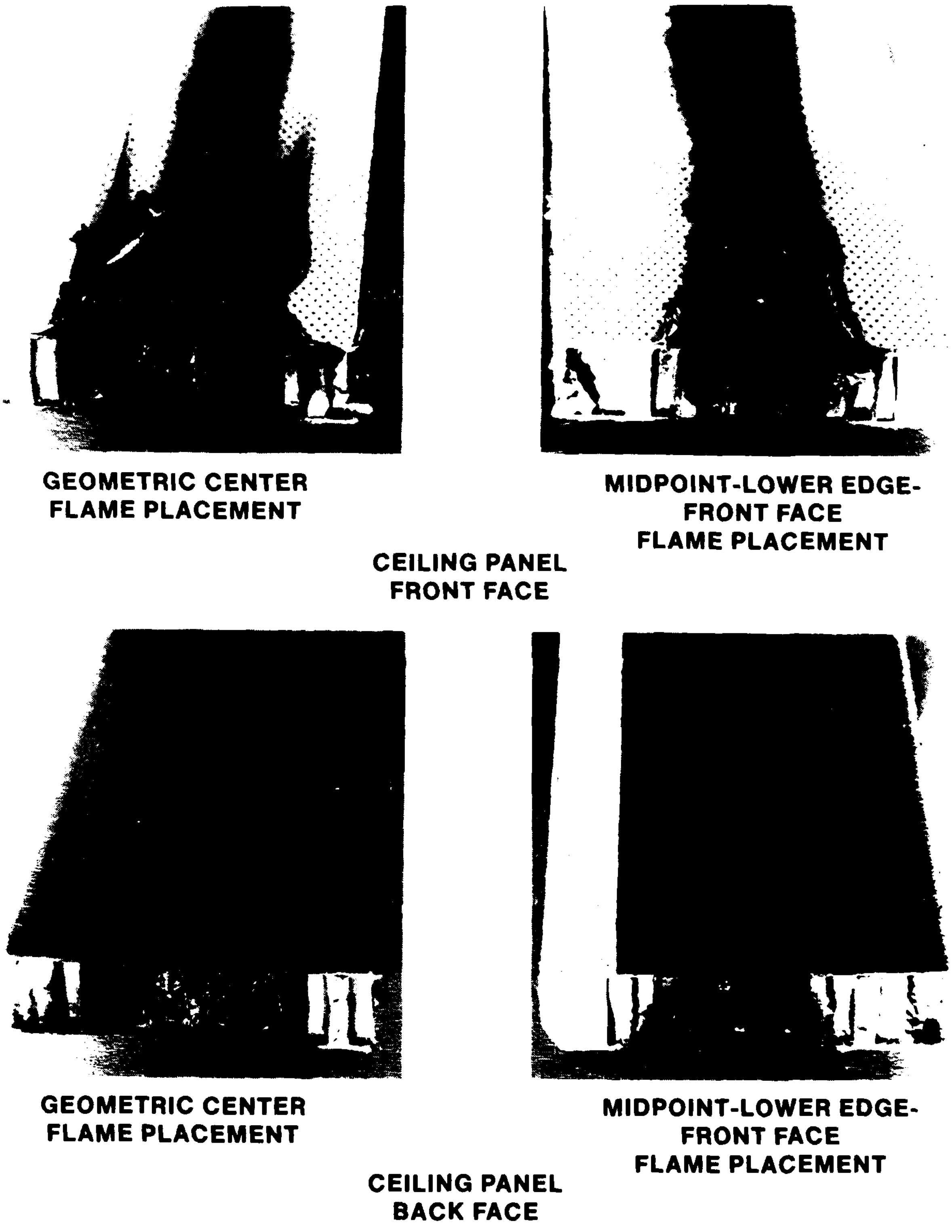


FIGURE 7. EFFECT OF FLAME PLACEMENT ON COMPOSITE BURN RESULTS (FRONT FACE, BACK FACE)

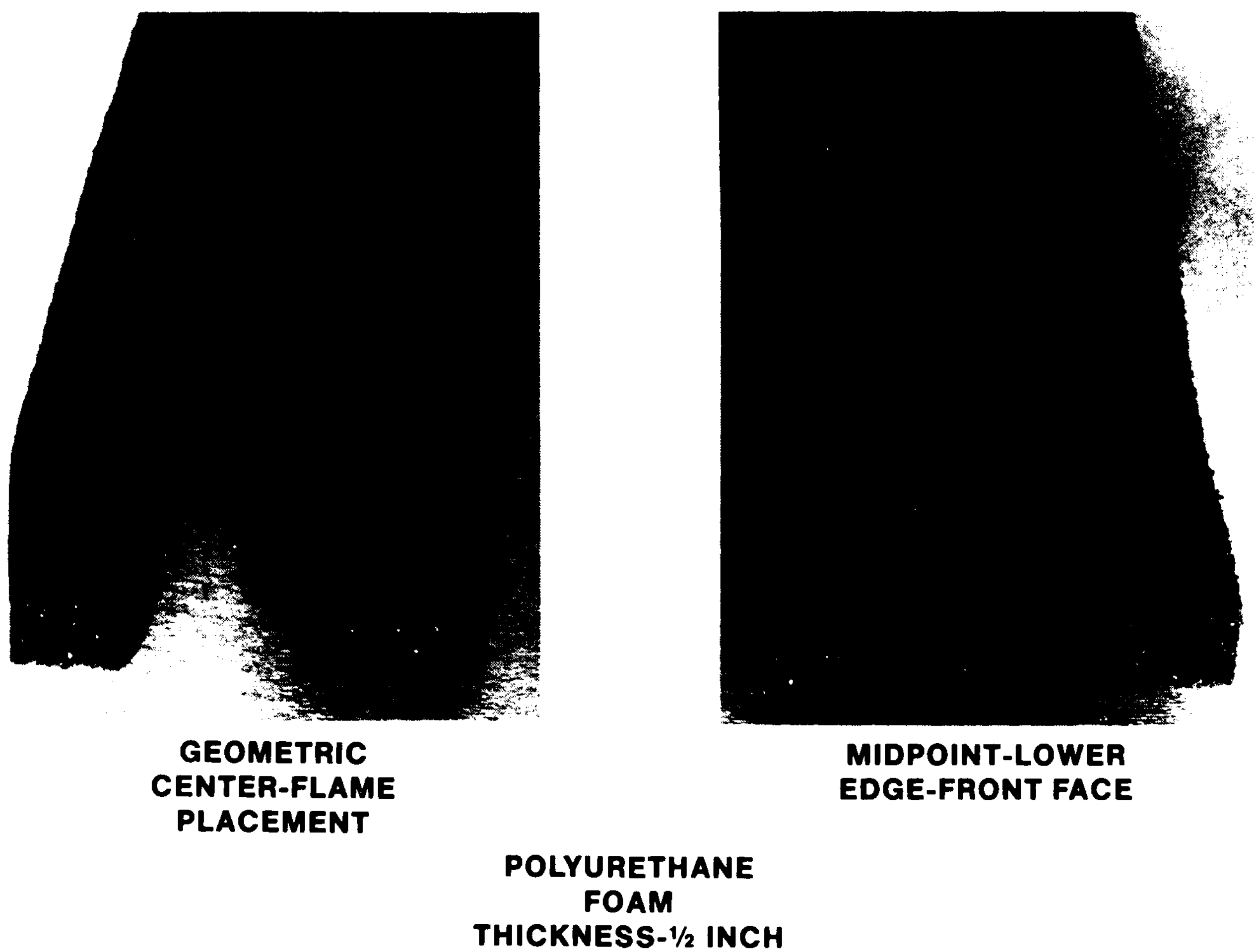


FIGURE 8. EFFECT OF FLAME PLACEMENT ON FOAM BURN RESULTS

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JET PROPULSION LABORATORY
4800 OAK GROVE DRIVE
PASADENA, CALIFORNIA 91103

MR. JOSEPH A. KRIST
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NEW YORK, NEW YORK 10018

DR. A. CARLOS FERNANDEZ-PELLO
MECHANICAL ENGINEERING DEPARTMENT
UNIVERSITY OF CALIFORNIA, BERKELEY
BERKELY, CALIFORNIA 94720

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1455 FAIRCHILD DRIVE
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SEATTLE, WA 98124

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WASHINGTON, DC 20234

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ASD/ENFEF
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LOS ANGELES, CALIF. 90009

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HOHOKUS, NEW JERSEY 07423

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P.O. BOX 3707, M/S 6F-26
SEATTLE, WASHINGTON 98124

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COLUMBUS, OHIO 43214

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WOODBURY, L.I., NEW YORK 11797

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MS/73-43
SEATTLE, WASHINGTON 98124

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INTERNATIONAL WOOL SECRETARIAT
TECHNICAL CENTER, VALLEY DRIVE
ILKLEY, WEST YORKSHIRE, LS29 8PB
ENGLAND

DR. JOHN O. PUNDERSON
E.I. DUPONT De NEMOURS
P.O. BOX 1217
PARKERSBURG, W. VA. 26102

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MINISTRY OF CONSTRUCTION
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TSUKUBA-GUN
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WASHINGTON, D.C. 20008

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P.O. BOX 18070
PITTSBURG, PA. 15236

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ENGINEERING DEPT.
SAN FRANCISCO INTERNATIONAL AIRPORT
SAN FRANCISCO, CALIF. 94128

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CIVIL BUSINESS GROUP
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YEOVIL, BA20 2YB
SOMERSET, ENGLAND

D.A. RADICE
MANAGER, FLEXIBLE SALES
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555 ALASKA AVE.
TORRENCE, CALIF. 90503

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JOHN SCHNELLER & ASSOCIATES
6019 POWDERMILL ROAD
KENT, OHIO 44240

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TRANSPORT CANADA
OTTAWA, ONTARIO, CANADA K1A0N8

MR. MIKE BAUCCIO
U.S. ARMY AVIATION R&D COMMAND
AVSCOM/DRSAV-DS
4300 GOODFELLOW BLVD.
ST. LOUIS, MISSOURI 63120

MR. CHARLES W. MCGUIRE
DEPT. OF TRANSPORTATION
400 7TH STREET S.W.
WASHINGTON D.C. 20590

MR. VYTO BABRAUSKAS
NATIONAL BUREAU OF STANDARDS
BLDG. 224, ROOM A-345
WASHINGTON D.C. 20234

MR. A.T. PEACOCK
DOUGLAS AIRCRAFT COMPANY
INTERNAL MAIL CODE 36-41
3855 LAKEWOOD BLVD.
LONG BEACH, CA. 90846

MR. PASCAL DRANITSARIS
ONTARIO RESEARCH FOUNDATION
SHERIDAN PARK RESEARCH COMMUNITY
MISSISSAUGA, ONTARIO, CANADA
L5K1B3

MR ERIC W. SIMMONS
ONTARIO RESEARCH FOUNDATION
SHERIDAN PARK RESEARCH COMMUNITY
MISSISSAUGA, ONTARIO, CANADA
L5K1B3

MR. V.W. BALLENGER
DIRECTOR, ENGINEERING AND MAINT.
AIR TRANSPORT ASSOCIATION
1709 NEW YORK AVE., NW
WASHINGTON, D.C. 20006

MR. JAMES H. KEELER
GENERAL ELECTRIC COMPANY
ONE PLASTICS AVE.
PITTSFIELD, MASSACHUSETTS 01201

MR. WILLIAM K. GREER
GENERAL ELECTRIC COMPANY
ONE PLASTICS AVE.
PITTSFIELD, MASSACHUSETTS 01201

MR. JIM BROWN
GENERAL DYNAMICS ELECTIC BOAT DIV.
STATION C62
EASTERN POINT ROAD
GROTON, CONN. 06340

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U.S. TESTING
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L.A., CA. 90040

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ATLANTA, GEORGIA 30320

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MINNEAPOLIS, MINNESOTA 55450

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MIAMI INTERNATIONAL AIRPORT
MIAMI, FL. 33148

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