AN EVALUATION OF THE FLAMMABILITY OF UPHOLSTERED FURNITURE COMPOSITES BY THE BRITISH "CRIB TEST"

T. L. Court*

J. R. Galloway**

R. S. Tobey**

E. I. du Pont de Nemours & Co. (Inc.)

*du Pont (U.K.) Limited
Elastomers Research Laboratory
Hemel Hempstead, Herts
England

**Polymer Products Department
Elastomers Division
Wilmington, Delaware, U.S.A.

A paper presented at the
Sixth International Conference
on Fire Safety, January 1981
Menlo Park, California

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INTRODUCTION

The test methods used in flammability standards and specifications for upholstered furniture vary from agency to agency and country to country. In the United States some standards specify the materials that must be used but do not include any test methods. An example is the Federal Prison Mattress Standard which requires cotton with a minimum boric acid content. However, most U.S. standards use small scale tests on components. Examples are the Department of Transportation standard for motor vehicle interiors, Federal Motor Vehicle Safety Standard 302, and the Port Authority of New York and New Jersey specification for upholstered furniture. Meanwhile, the British appear to have adopted the philosophy that the three hazards of life safety (smoke, heat, toxicity) are best controlled by reducing the chances of ignition. Also, in Great Britain, the trend on a federal level is away from small scale testing and toward full scale test methods using graduated ignition sources that have been designed to give a wide range of intensity. We refer to this test method as the British "crib test" and it will be described in detail later.

It is generally accepted that small scale component tests do not predict actual performance in a real fire. Small scale testing of composites undoubtedly comes closer and the British system closer yet. Even so, there are some questions concerning the British test method. One is how the ignition source compares to a real life situation. Another question is how does the test mock-up configuration compare with various actual upholstered furniture items.

In the final analysis, however, it does not matter what tests are used to write the flammability specification for a furniture item. The only thing that matters is whether the furniture item will perform satisfactorily in an actual fire. At the present state of the art, the only sure way to determine performance is to test the actual piece of furniture with an ignition source that is reasonable in the environment in which the furniture will be used.

OBJECTIVE

Our objective is to examine the relationship between the British full-scale crib test and several typical small scale USA flammability tests of upholstery composites and their components, and their ability to indicate relative flammability performance.

EXPERIMENTAL

Test Materials

A series of combinations of various fabrics, an interliner and cushioning foam were used in this evaluation.

Cushioning

The cushioning foam for the composites reported here was 32 kg/m^3 (2.0 lb/ft^3) HR polyether urethane foam. In half of the experiments, VONAR® 3 interliner on a fiberglass scrim was used around the foam as a protective barrier while, in the other half of the experiments, no interliner was used.

VONAR® interliners are thin layers of cellular polychloroprene material made by Du Pont licensees to a Du Pont specification. They are intended to be used as a protective layer completely enclosing the cushioning material in interior furnishings. When properly used, according to Du Pont guidelines, VONAR® will prevent or significantly delay ignition of the cushioning material it envelops when the ignition source is typical and of a reasonable size; e.g., cigarettes or wastebasket trash for upholstered furniture.

Fabrics

The cover material used on the cushions tested in this work were the five fabrics most commonly used by the largest purchaser of institutional furniture in Britain, the Property Services Agency of the Dept. of Environment. The description of these fabrics is given in Table I:

Table I

Fabric Description

Fiber Content	Mass/Area g/m^2	Mass/Area (oz/yd^2)	Weave	Color
Nylon	237	(7.0)	double knit	yellow and orange
Polyester	271	(8.0)	double knit	blue on grey
Cotton	203	(6.0)	twill	grey and gold on white
Modacrylic	407	(12.0)	cut velvet	ruby
Wool	797	(23.5)	moquette	red, black and grey

Small Scale Tests

The materials used in the upholstery composites were evaluated as components in the following small scale tests:

- ASTM E162-79 (radiant panel)
- ASTM D2863-77 (oxygen index)
- ASTM F501-77 (vertical burn)
- Federal Test Method 191.5903 (vertical burn)

Composites of all fabrics with and without interliners over HRPU foam were evaluated by the following tests:

- ASTM E162-79 (radiant panel)

- Modified California Technical Information Bulletin 117, Section DII (cigarette smoldering)

RESULTS

In discussing the results of this evaluation it should be pointed out that these numerical flammability values are not intended to reflect hazards presented by these materials under actual fire conditions. As stated earlier the test materials described were tested as components and as composites with and without the VONAR® interliner. The results of the tests on the components will be discussed first.

SMALL SCALE COMPONENT TESTS

Vertical Burn (ASTM F501, F.T.M. 191.5903)

These methods are basically similar. A standard size piece 76 x 305 mm (3" x 12") of fabric is supported vertically in a metal frame and ignited with a gas burner at the bottom edge. The ignition time is two seconds for ASTM F501 and twelve seconds for Federal Test Method 191.5903. After removal of the ignition flame the time for the flame to go out, for glowing to stop, and amount consumed are measured. In our tests, the burning characteristics were generally the same in both directions of the fabric and the average of the two values was used, except as noted for wool in the Federal Test Method. The data are presented in, Table II.

Table II

Vertical Burn

12 sec exposure

2 sec exposure

Fabric	ASTM F 501 Time, s Flame	ASTM F 501 Time, s Glow	ASTM F 501 % Consumed	F.T.M.191.5903 Time, s Flame	F.T.M.191.5903 Time, s Glow	F.T.M.191.5903 % Consumed
Polyester	22	0	35	15	0	26
Modacrylic	1	0	2	16	2	70
Cotton	32	85	100	24	52	100
Nylon	38	0	44	28	0	52
Wool	1	0	nil	28	49	22 warp
				267	24	100 fill

The ASTM F501 results show that the modacrylic and wool fabrics are the best, with cotton being the worst. The Federal Test Method indicates that the polyester fabric is the best with modacrylic, cotton and wool the worst. The values for warp and fill directions for wool are both shown because the differences were too large to be averaged. The more severe ignition source (12 seconds) of the Federal Test Method tends to equalize the flammability performance of the fabrics and not show the large differences experienced with ASTM F501.

Oxygen Index (ASTM D2863)

This test is run on small specimens in a controlled atmosphere of an oxygen/nitrogen mixture. The specimen is held vertically and lighted at the top with a gas flame. Burning time and distance burned are measured. The index is determined by the minimum volume percent of oxygen in the gas mixture that will just support candle-like burning. (The higher the index, the better the performance). It should be pointed out that these tests were run at room temperature (21°C-70°F) and that the index decreases as the test temperature is raised. (Reference 1) Table III gives the results of this test procedure.

Table III

Oxygen Index (ASTM D2863)

Fabric	Vol. % Oxygen
Polyester	30
Modacrylic	31
Cotton	20
Nylon	23
Wool	30
HR PU Foam	24
VONAR® 3	60

These data indicate that the wool, polyester, and modacrylic fabrics have the best indexes. However, only the wool and modacrylic fabrics correlate with the ASTM vertical burn results.

Also, only polyester appears to correlate with the Federal vertical burn test. The indexes for the HR polyurethane foam and VONAR® are shown for background information.

Radiant Panel (ASTM E162)

This method employs a radiant heat source consisting of a 305 x 457 mm (12 x 18 inch) panel at 670°C in front of which an inclined 152 x 457 mm (6 x 18 inch) specimen is placed. Ignition by a flame is near the upper edge of the specimen and the flame front progresses downward. The product of the factor derived from the rate of progress of the flame front and another relating to the rate of heat liberation by the material gives the flame spread index. The lower the index, the better the performance.

This test method is used quite universally for components and composites. It is considered by many to be the most reliable and prognostic of the small scale tests, Table IV.

Table IV

Radiant Panel (ASTM E162)

Fabric	Flame Spread Index, I_s
Polyester	5
Modacrylic	18
Cotton	354
Nylon	7
Wool	308 surprising
HR PU Foam	383
VONAR® 3	3

These data indicate gross differences in the fabric performance, with cotton and wool being the worst. Again, the index for the HR polyurethane foam and VONAR® 3 interliner are shown for background information.

It is widely accepted that small scale flammability tests on components are often of little value in judging the flammability characteristics of materials. This can be seen quite readily in this evaluation when the fabrics are examined across the board in all the tests. For example, Table V shows the data for nylon and wool:

Table V

Small Scale Tests

	ASTM F501 Vertical Burn % Consumed	F.T.M. 191.5903 Vertical Burn % Consumed	Oxygen Index Vol. % O_2	Radiant Panel I_s
Nylon	44	52	23	7
Wool	nil	61	30	308

Whereas the nylon fabric is worse than wool in one vertical burn test and oxygen index, and is about equal in the other vertical burn test, it is far superior in the radiant panel test. Thus, it is difficult to choose a specific small scale test that will be representative of actual fire performance.

SMALL SCALE COMPOSITE TESTS

There are only a few small scale test methods in which composites can be evaluated. One of these is the smoldering test for resilient cellular materials in California Technical Information Bulletin No. 117 Section D II. In this test a burning cigarette is placed on a small scale upholstered seating mock-up and covered with cotton sheeting. Weight loss due to smoldering is determined. Although this test is intended to screen cellular cushioning materials using a standard fabric, we used it to test these 5 different fabrics. All of the fabrics were tested by this method with and without VONAR® 3. Weight losses ranged from nil to less than 2 percent. Therefore, our modification to the method is not suitable as a means of differentiating between these upholstery constructions. A more intense ignition source must be used.

For example, the radiant panel test described earlier is a commonly used test where composites can be evaluated at a higher level of heat flux. The various fabrics were tested over the HR polyurethane foam as well as with a VONAR® 3 interliner between the fabric and the foam. The results of this testing are shown in Table VI.

good!

Table VI

Radiant Panel (ASTM E162)

	Flame Spread Index, I_s Fabric/HR PU	Flame Spread Index, I_s Fabric/VONAR® 3/HR PU
Polyester	228	80
Modacrylic	188	37
Cotton	348	147
Nylon	183	30
Wool	326	179

These data show that VONAR® 3 interliner greatly improves the flame spread index of all constructions although it does not change the relationship of the fabrics to each other.

Table VII summarizes the results of the small scale testing by ranking the performance of the fabrics.

Table VII

Small Scale Test Rankings*

	Components				Composites	
	ASTM F501 Vert. Burn	Fed. 191.5903 Vert. Burn	ASTM D2863 O_2 Index	ASTM E162 Rad. Panel	ASTM E162 Rad. Panel**	Cal. 117 Cig. Smld
Polyester	2	1	1	1	2	1
Modacrylic	1	3	1	2	1	1
Cotton	4	4	3	4	3	1
Nylon	3	2	2	1	1	1
Wool	1	2	1	3	3	1

*Rankings: 1= best. Rankings have no value, that is the difference between 1 and 2 is not the same as between, say, 3 and 4.

**With and without VONAR® 3

With the possible exception of the radiant panel test, no correlation can be found between these small scale component and composite tests.

RESULTS FULL-SCALE TESTS

British Crib Tests

The crib tests were performed by the Rubber and Plastics Research Association (RAPRA) at their Technical Center at Shawbury, England according to procedures of The Department of Environment, Property Services Agency, Fire Retardant Specification No. 4 titled "Composite Upholstery Ignition Standard". (Reference 2) For brevity, we will refer to this as DOE.PSA FR4 or the British Crib Test. The purpose of this standard is to assess the likely ignition behavior of composites of upholstery components in a full scale test. The requirements of DOE.PSA FR4 are that a determination be made of the minimum amount of ignition source necessary to cause sustained burning of a full scale composite upholstery mock-up. In this evaluation the mock-up consisted of a seat cushion 450 mm wide by 300 mm deep and 75 mm thick (18 x 12 x 3 in) and a back cushion 450 mm wide by 600 mm high and 75 mm thick (18 x 24 x 3 in). The mock-up cushions were held in place with a perforated steel rig simulating a chair as shown in Fig. 1.

The ignition sources used in DOE. PSA FR4 vary from a smoldering cigarette to multiple wood cribs made of pine sticks. In this evaluation, wood cribs were placed on the seat cushion at the junction with the back cushion which were, in turn, ignited by lighting wood shavings inside the crib with a match. Sustained burning is defined as lasting at least two minutes after the crib extinguishes.

This test represents a major difference vs most USA test methods which use a constant ignition source and give differences in performance. The crib test tends to give relatively equal performance by varying the ignition source.

This work used crib numbers 5, 6, 7, 2x7, and 4x7. The specific data on each of these ignition sources are given in Figs. 2-5. The pictures show the cribs before ignition and at their burning peak. For comparative purposes, a No. 5 crib of 17g is approximately equal in caloric value to one double sheet of newspaper.

RAPRA has found that the fire generated by the cribs is more severe and reproducible than that from crumpled newspapers with equivalent caloric content. This is because the crib has a uniform structure versus the variability of crumpled newspapers. Also, the crib is not constantly shifting during the burn, there is a much larger mass of burning embers, and the crib has better contact with the upholstery.

The minimum size of the crib required to make the various constructions burn more than 120 seconds after the crib extinguishes is a measure of its ignition resistance. The results obtained are shown in the following photographs of the composites after burning. Figs. 7-16.

The data obtained are summarized in Table VIII.

Table VIII

British Crib Test (DOE.PSA FR4)

	Crib Size (g)		Estimated % Consumed	
	Fabric/HRPU	Fabric/VONAR® 3/HRPU	Fabric/HRPU	Fabric/VONAR® 3/HRPU
Polyester	17	504	50	40
Modacrylic	63	504	85	40
Cotton	17	126	90	10
Nylon	17	252	90	20
Wool	126	504	15	25

These results indicate that:

1. VONAR® 3 greatly improved the flammabilty performance of all systems.
2. ~~The wool fabric performed best in these British full-scale tests with and without VONAR® 3.~~
3. VONAR® 3 improved the performance of wool and raised the level of performance of the modacrylic and polyester fabrics up to that of wool.
4. One improvement to the crib test might be to use smaller gradations of crib size or to use combinations of various sizes in order to obtain a closer determination of the ignitability level of the article.

SMALL VERSUS LARGE SCALE COMPOSITE TESTS

Although we cannot find a good correlation between small scale component tests and small or large scale composite tests, an examination of the data obtained on composites evaluated by the Radiant panel test and the large scale crib test is interesting. The data are presented as rankings in order to be more easily assimilated, Table IX.

Table IX

Small Versus Large Scale Composite Tests

Rankings (1 = best)

	Radiant Panel	British Crib
Modacrylic/VONAR® 3/HRPU	1	1
Polyester/VONAR® 3/HRPU	2	1
Wool/VONAR® 3/HRPU	3	1
Nylon/VONAR® 3/HRPU	1	2
Cotton/VONAR® 3/HRPU	3	3
Wool/HRPU	5	3
Modacrylic/HRPU	3	4
Polyester/HRPU	4	5
Nylon/HRPU	3	6
Cotton/HRPU	5	6

The radiant panel rankings are based on the flame spread index and British crib rankings are based on the size of the crib required for ignition. The rankings have no value, i.e., the difference between 1 and 2 is not the same as between, say 3 and 4 or 5 and 6.

These data indicate that there is poor correlation between the radiant panel and the British crib tests.

SUMMARY AND CONCLUSIONS

1. There is little correlation between various small scale flammability tests of upholstery components.

2. Small scale flammability tests on components are of questionable value in judging the flammability performance of materials in a real fire situation.

3. With the possible exception of the radiant panel test, no correlation can be found between these small scale component and composite tests.

4. There appears to be poor correlation between composites tested by the radiant panel and the British crib test.

5. VONAR® 3 greatly improves the flammability performance of all the composites in both small and large scale tests.

6. The British crib test appears to have merit as a reproducible method of determining the ignition performance of upholstered furniture composites and warrants investigation to determine how it might fit into the United States codes and standards.

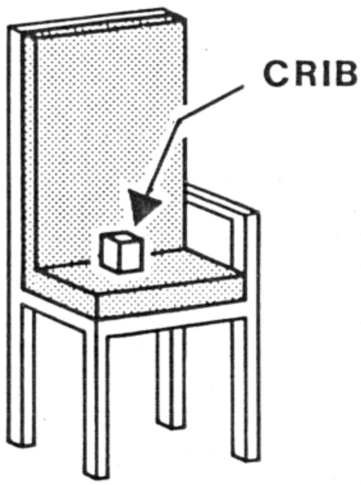
REFERENCES

1. P. R. Johnson, Journal of Applied Polymer Science, 18 No. 2 pp 491-504 (February, 1974)

2. RAPRA , Confidential Technical Report, No. 5417, (January 14, 1980)

FIGURE 1

UPHOLSTERED FURNITURE MOCK-UP



BACK CUSHION - 450 mm WIDE
- 600 mm HIGH
- 75 mm THICK

SEAT CUSHION - 400 mm WIDE
- 300 mm HIGH
- 75 mm THICK

FRAME - PERFORATED STEEL

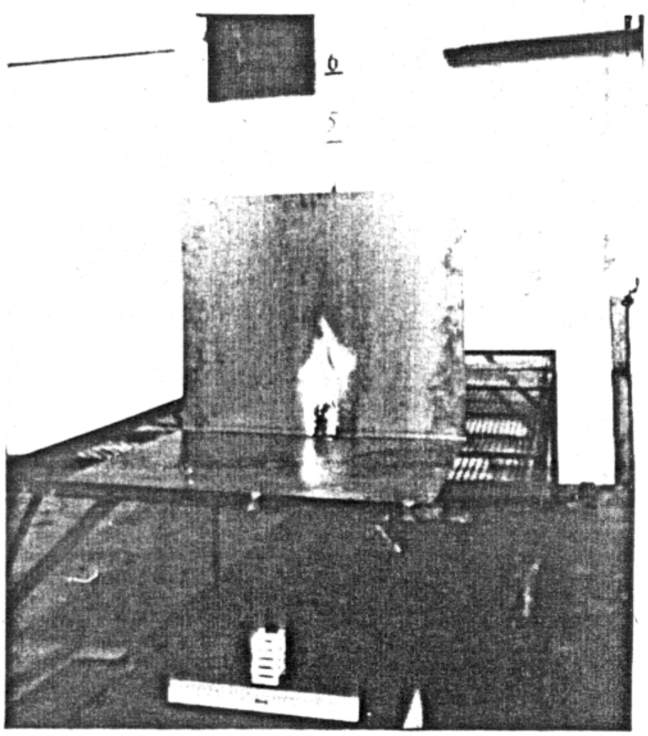


FIGURE 2- **NUMBER 5 CRIB**
MASS- 17 g
SIZE- 20 PIECES-
6 1/2 X 6 1/2 X 40 mm
PEAK AT 120 s (APPROX)
FLAME OUT 180 s (APPROX)

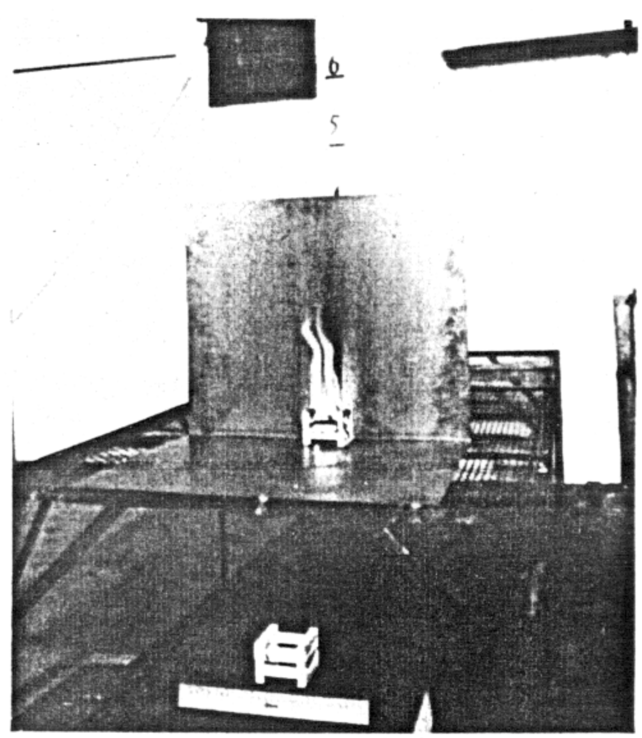


FIGURE 3- **NUMBER 6 CRIB**
MASS- 63 g
SIZE- 10 PIECES-
12 1/2 X 12 1/2 X 80 mm
PEAK AT 135 s (APPROX)
FLAME OUT 480 s (APPROX)

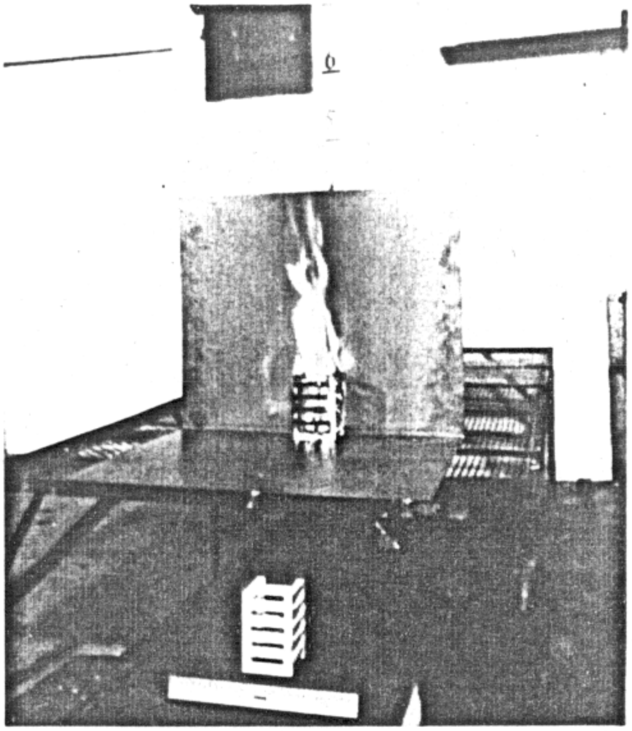


FIGURE 4- **NUMBER 7 CRIB**
MASS- 126 g
SIZE- 20 PIECES-
12 1/2 X 12 1/2 X 80 mm
PEAK AT 150 s (APPROX)
FLAME OUT 510 s (APPROX)

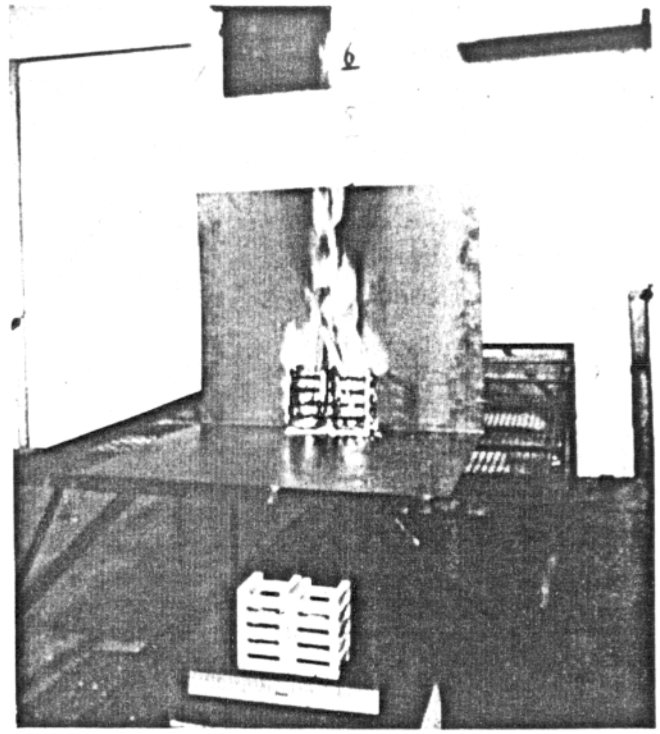


FIGURE 5- **2 NUMBER 7 CRIBS**
MASS- 252 g
SIZE- 2 NUMBER 7 CRIBS
PEAK AT 210 s (APPROX)
FLAME OUT 510 s (APPROX)

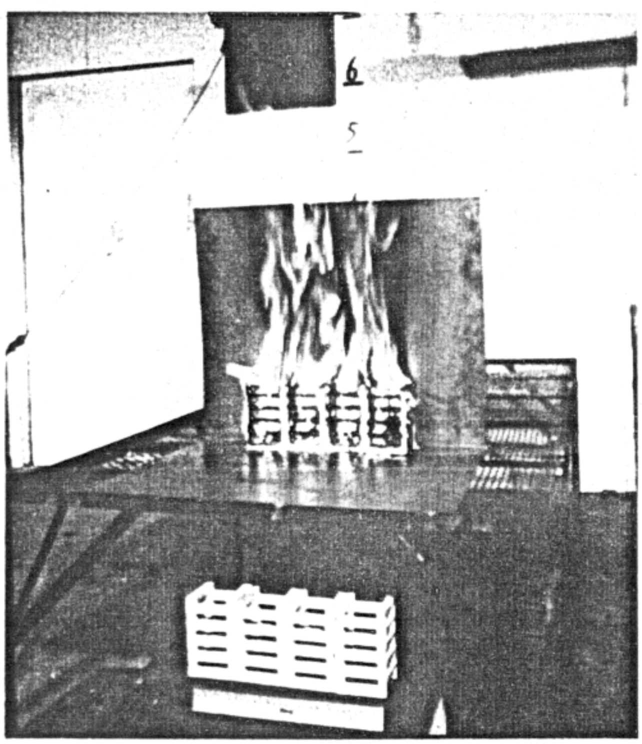


FIGURE 6- **4 NUMBER 7 CRIBS**
MASS- 504 g
SIZE- 4 NUMBER 7 CRIBS
PEAK AT 210 s (APPROX)
FLAME OUT 585 s (APPROX)

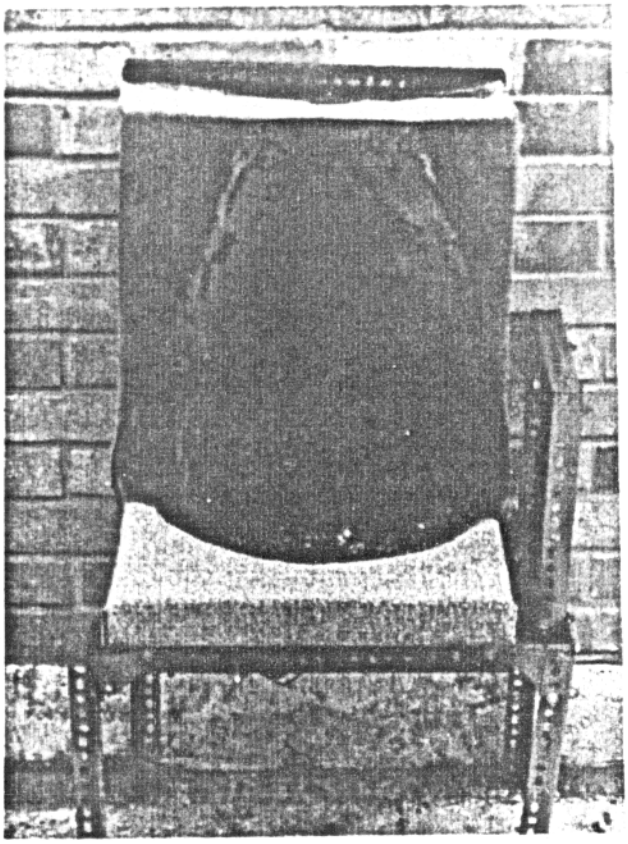


Figure 7- **POLYESTER/HR PU**
17 g CRIB

Figure 8- **POLYESTER/VONAR® 3/HR PU**
504 g CRIB

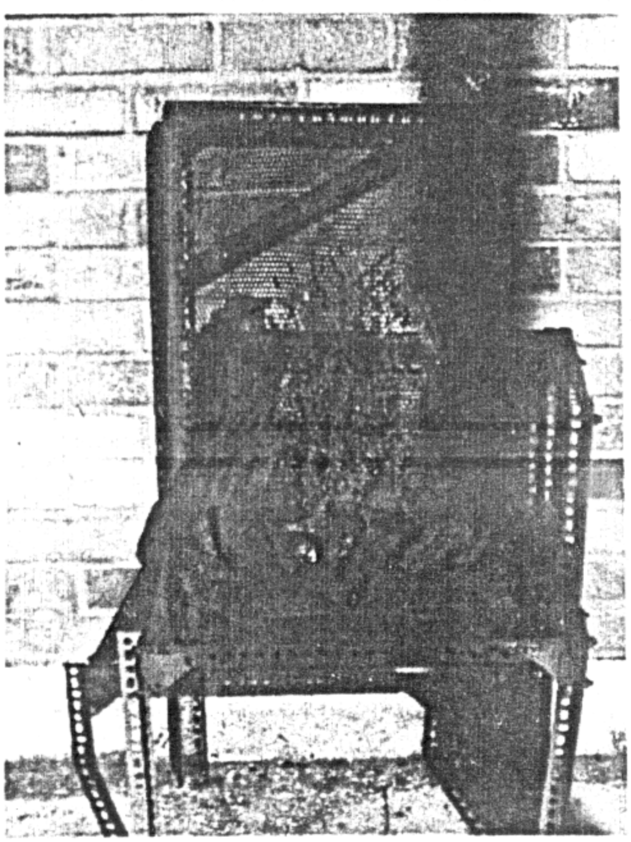


Figure 9- **MODACRYLIC/HR PU**
63 g CRIB

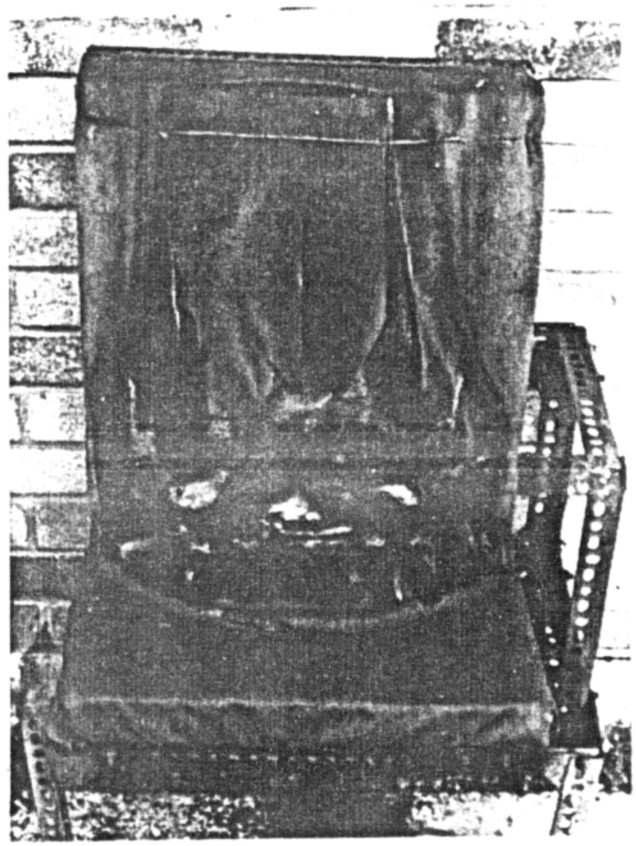


Figure 10- **MODACRYLIC/VONAR® 3/HR PU**
504 g CRIB

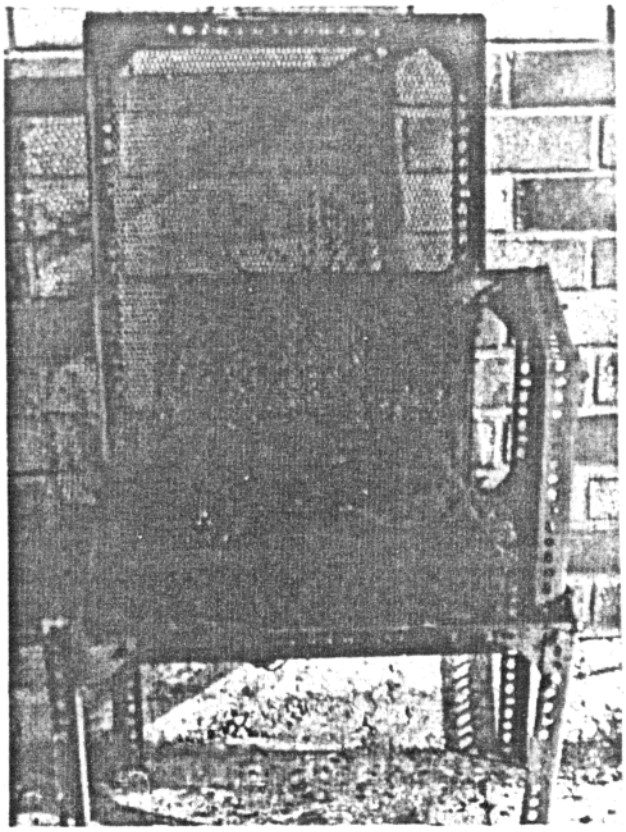


Figure 11- **COTTON/HR PU**
17 g CRIB

Figure 12- **COTTON/VONAR® 3/HR PU**
126 g CRIB

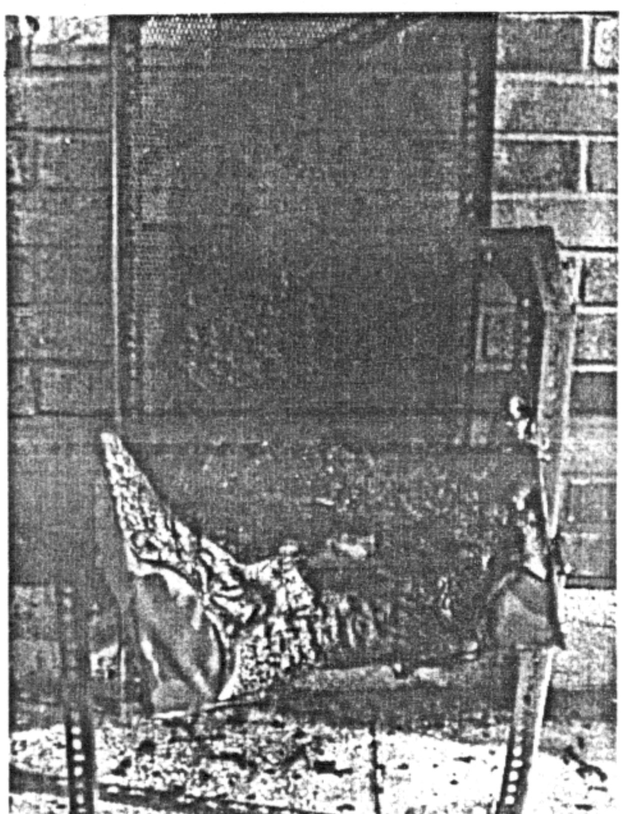


Figure 13- **NYLON/HR PU**
17 g CRIB

Figure 14- **NYLON/VONAR® 3/HR PU**
252 g CRIB

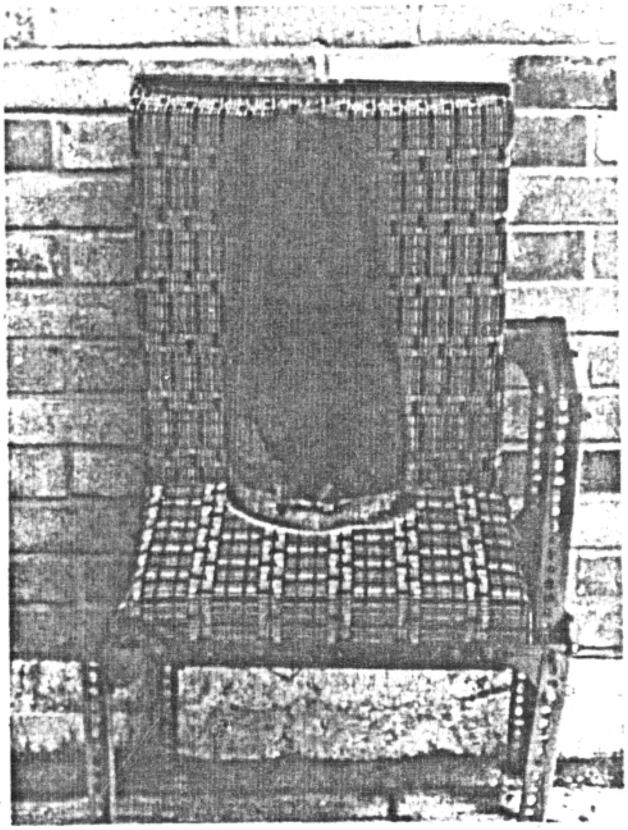


Figure 15- **WOOL/HR PU**
126 g CRIB

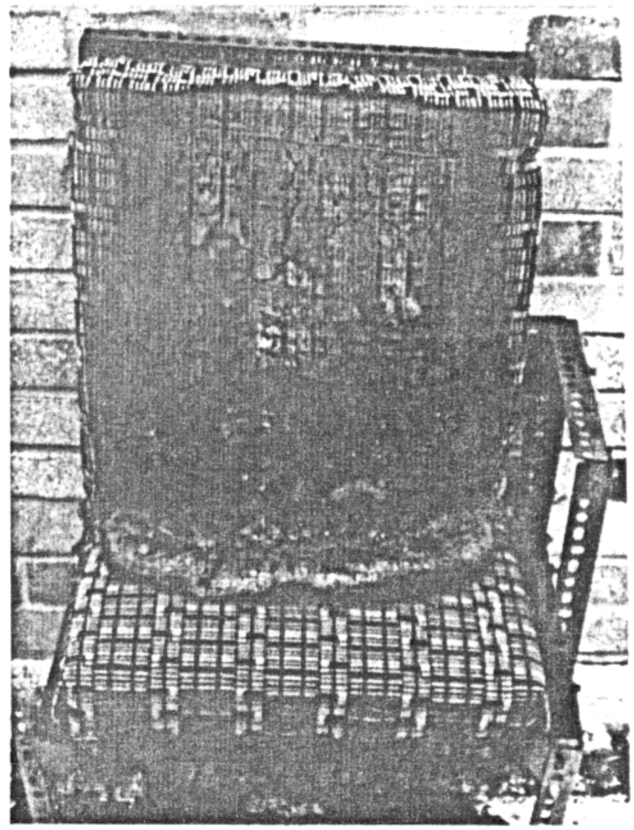


Figure 16- **WOOL/VONAR®3/HR PU**
504 g CRIB