FATIGUE OF SANDWICH CONSTRUCTIONS FOR AIRCRAFT

(Glass-fabric-laminate Facing and Alkyd Isocyanate Foamed-in-place Core Sandwich Material, Tested in Shear)

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FATIGUE OF SANDWICH CONSTRUCTIONS FOR AIRCRAFT[1]

(Glass-fabric-laminate Facing and Alkyd Isocyanate Foamed-in-place Core Sandwich Material, Tested in Shear)[2]

By

FRED WERREN, Engineer

Forest Products Laboratory,[3] Forest Service
U. S. Department of Agriculture

Summary and Conclusions

A limited number of tests were made at the Forest Products Laboratory to determine the shear fatigue properties of a sandwich panel

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[1]This progress report is one of a series prepared and distributed by the Forest Products Laboratory under U. S. Navy, Bureau of Aeronautics Order No. NAer 01237 and 01202, and U. S. Air Force No. USAF-(33-038) 51-4062E. Results here reported are preliminary and may be revised as additional data become available.

[2]This is the eleventh of a series of reports intended to offer a comparison of the shear fatigue properties of different sandwich materials. The following Forest Products Laboratory reports discuss the shear fatigue properties of:

1559 "Cellular Cellulose Acetate Core Material"
1559-A "Aluminum Face and Paper Honeycomb Core Sandwich Material"
1559-B "Aluminum Face and End-grain Balsa Core Sandwich Material"
1559-C "Aluminum or Fiberglas-laminate Face and Fiberglas Honeycomb Core Sandwich Material"
1559-D "Fiberglas-laminate Face and End-grain Balsa Core Sandwich Material"
1559-E "Aluminum or Fiberglas-laminate Face and Cellular-hard-rubber Core Sandwich Material"
1559-F "Cellular Cellulose Acetate Core Material with Aluminum or Fiberglas-laminate Facings"
1559-G "Fiberglas-laminate Facing and Paper Honeycomb Core Sandwich Material"
1559-H "Aluminum Facing and Aluminum Honeycomb Core Sandwich Material"
1559-I "Glass-fabric-laminate Facing and Waffle-type Core Sandwich Material"

[3]Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

with facings of glass-fabric laminate and a core of alkyd isocyanate foamed in place. Repeated tests were made at a ratio of minimum to maximum loading of 0.1. The results of the tests indicate that the fatigue strength at 30 million cycles is about 30 percent of the static strength for the condition of loading used.

Introduction

If plates of sandwich construction are designed so that their facings are elastically stable, the most critical stress to which the core is subjected is shear. The consideration of the effect of repeated shear stresses on the material of the cores and on the bonds between the core and facings is therefore important.

Sandwich material with facings of glass-fabric laminate and a core of alkyd isocyanate foamed in place was tested in shear to determine its fatigue strength. The general testing procedures and the nomenclature applied in these tests are similar to those used by the Forest Products Laboratory in testing sandwich material with aluminum facings and paper-honeycomb cores.[2]

Description of Material

All test specimens were cut from a single assembled sandwich panel, 18 by 30 inches, that was purchased from the manufacturer in May 1951. Details of fabrication are not known, but the panel was believed to conform with certain requirements specified by the Forest Products Laboratory. These requirements were: (1) The panel should have a 1/2-inch core of alkyd isocyanate foam (core 37); (2) the facings should be eight-ply, cross-laminated 112-114 glass fabric impregnated with resin 2; and (3) the core material should be foamed in place between the two cured facings with the facings placed on edge (vertical). The density of the core material, calculated from the control specimens, varied from 8.9 to 10.0 pounds per cubic foot (fig. 1). The panel varied in thickness from 0.562 to 0.579 inch.

Specimens 2 inches wide and 5.67 inches long were cut from the sandwich panel with a high-speed steel circular saw, according to the cutting diagram shown in figure 1. Considerable care was required in the sawing operation to prevent fracture of the core near the facing. Later experience showed that this material could be readily cut with a sharp band saw.

The sandwich specimens were glued to the 1/2-inch shear plates with an epoxy-resin adhesive. The adhesive was cured at 10 pounds of pressure per square inch and 100° F. for 16 hours.

Testing

All tests were made by methods similar to those described in Forest Products Laboratory Report No. 1559-A,[2] except that the specimens were conditioned and tested in an atmosphere of 75° F. and a relative humidity of 50 percent.

The failure of both control and fatigue specimens was rapid once it began. The type of failure varied considerably, and it appeared to depend largely upon the position of the specimen in the original sandwich panel. Specimens from near the top of the sandwich panel (fig. 1) failed primarily through the central part of the core. Specimens from the bottom part of the panel also failed in the core, but in the row of cells (bubbles) adjacent to the facing. Typical shear failures from three locations in the panel are shown in figure 2. A photomicrograph of the surface adjacent to a facing in one of the bottom specimens is shown in figure 3. Careful examination of this surface showed that the apparent bubbles approximate hollow half-spheres (craters).

Specimens were cut both parallel and perpendicular to the direction of foaming. The types of failure were about the same for each direction of loading, depending upon their location in the original panel.

Presentation of Data

Table 1 presents the results for the individual fatigue and control specimens. Four specimens withstood more than 30 million cycles without failure. Values for control specimens are listed adjacent to the corresponding fatigue specimens. An estimate of the percentage of core failure in the first row of cells adjacent to the facing is also given.

Analysis of Data

Each control specimen was measured and weighed before being glued to the shear plates. By assuming an average weight and thickness of the facings, it was possible to make a reasonable estimate of the core density for each specimen. The values for the core weight of the control specimens are shown in figure 1 and vary between 8.9 and 10.0 pounds per cubic foot.

The shear strength of the core material did not vary in proportion to the density. The strength near the top of the panel, that is, the section which was foamed last, was about 15 to 30 percent higher than the strength near the bottom of the panel. There was also a distinct difference between the types of failure in specimens from these two parts of the panel. The type of failure was about the same, however, for specimens tested in the shear plane parallel or perpendicular

to the direction of foaming. There is an indication that the shear strength perpendicular to the direction of foaming may be slightly higher than the strength parallel to the direction of foaming, but no definite statement can be made from these limited tests.

A single S-N curve was drawn through the plotted points (fig. 4) to show the trend of the shear fatigue data. Fatigue properties parallel and perpendicular to the direction of foaming appear to be about the same. Prior to testing, it was agreed to discontinue any tests after 30 million cycles without failure. Four such specimens were removed from the machine. The curve indicates that the fatigue strength at 30 million cycles is about 30 percent of the static strength for the condition of loading used.

Table 1.--Shear fatigue strength of sandwich constructions with facings of glass-fabric laminate and a core of alkyd isocyanate foamed in place

Fatigue tests					Control tests		
Specimen No.	Maximum repeated shear stress	Ratio of maximum repeated shear stress to control strength[1]	Cycles to failure[2]	Core failure adjacent to facing	Specimen No.	Shear strength	Core failure adjacent to facing
	P.s.i.	Percent		Percent		P.s.i.	Percent
Tested in Direction of Foaming							
4	39.3	39.4	208,400	98	1	95.9	98
7	23.0	23.0	30,432,900+	No failure	10	103.6	95
13	77.8	78.0	201	99			
16	28.6	28.7	30,827,900+	No failure	Av.	99.8	
2	52.3	45.9	48,000	90	5	114.7	95
8	29.6	26.0	33,112,300+	No failure	14	113.2	98
11	74.1	65.0	1,500	95			
17	33.5	29.4	2,018,300	98	Av.	114.0	
3	43.6	34.1	587,200	1	9	124.6	5
6	38.4	30.0	1,089,200	5	18	131.4	5
12	69.2	54.0	10,700	5			
15	37.1	29.0	33,517,600+	No failure	Av.	128.0	
Tested Perpendicular to Direction of Foaming							
2a	54.1	41.4	86,200	1	1a	124.8	10
3a	41.2	31.5	13,797,800	50	4a	133.8	5
5a	64.4	49.3	41,600	65	7a	128.2	98
6a	94.1	72.0	2,700	10	19a	135.5	85
8a	103.1	78.9	400	95			
17a	38.6	29.6	9,243,200	2	Av.	130.6	
18a	38.6	29.6	23,289,400	55			
20a	96.6	74.0	250	95			
9a	46.3	38.2	679,800	97		[3]121.3	
10a	37.3	30.7	20,305,200	95		[3]121.3	
11a	70.5	63.0	2,000	99	12a	112.8	90
13a	39.2	35.0	708,800	98	15a	111.1	98
14a	64.9	58.0	4,300	99			
16a	37.0	33.0	2,983,400	99	Av.	112.0	

[1]For each group of specimens the average shear strength for the corresponding control specimens was used to determine this ratio.

[2]A plus sign following the number of cycles indicates the specimen was capable of resisting additional repeated stress at that particular stress level.

[3]Average of strength values for preceding and succeeding groups of specimens.

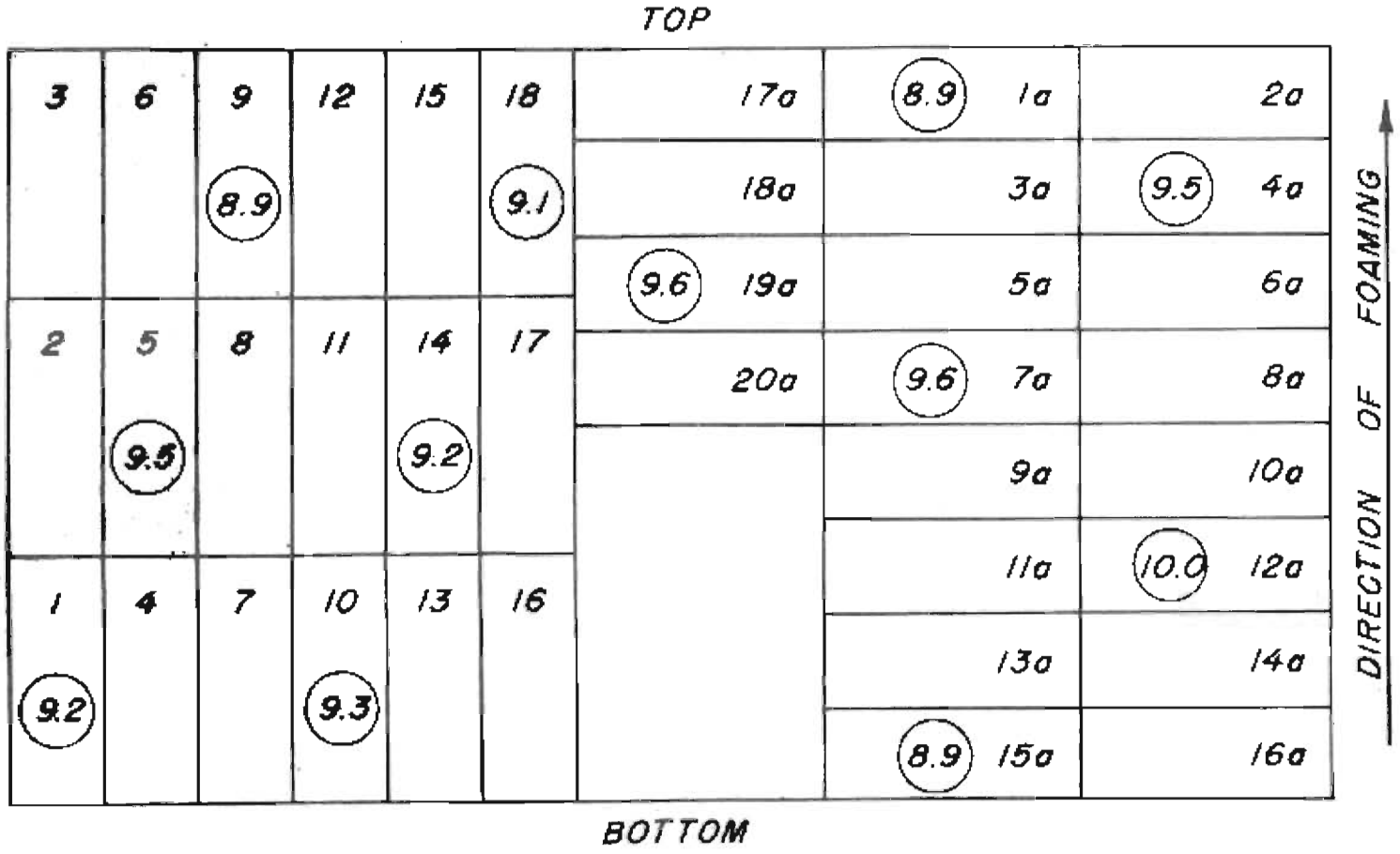

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Figure 1.--Diagram showing location of test specimens in a sandwich panel with facings of glass-fabric laminate and a core of alkyd isocyanate foam. Circled numbers indicate the approximate weight (pounds per cubic foot) of the core material in each control specimen.

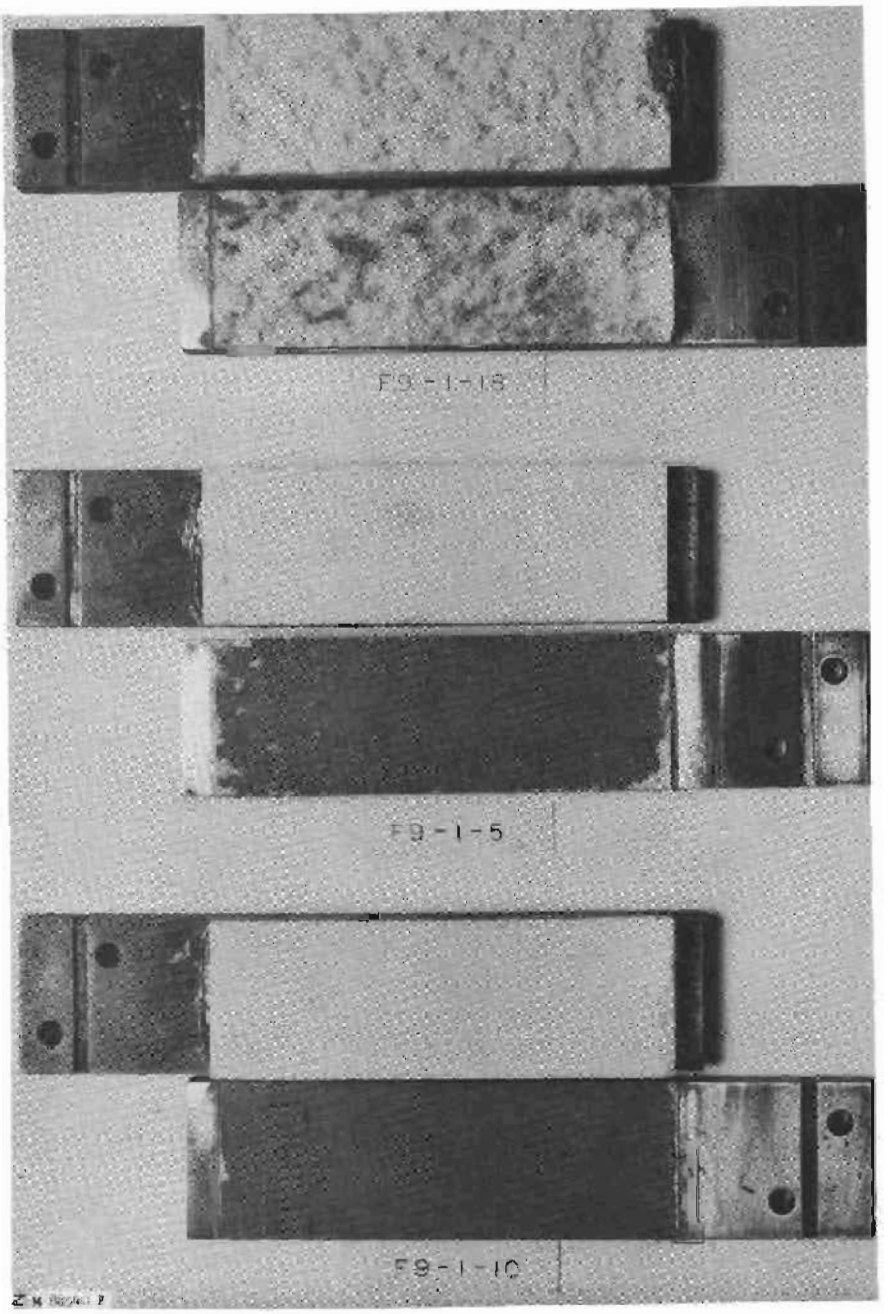

Figure 2.--Typical failures of shear specimens from a sandwich panel with facings of glass-fabric laminate and a core of alkyd isocyanate foam.

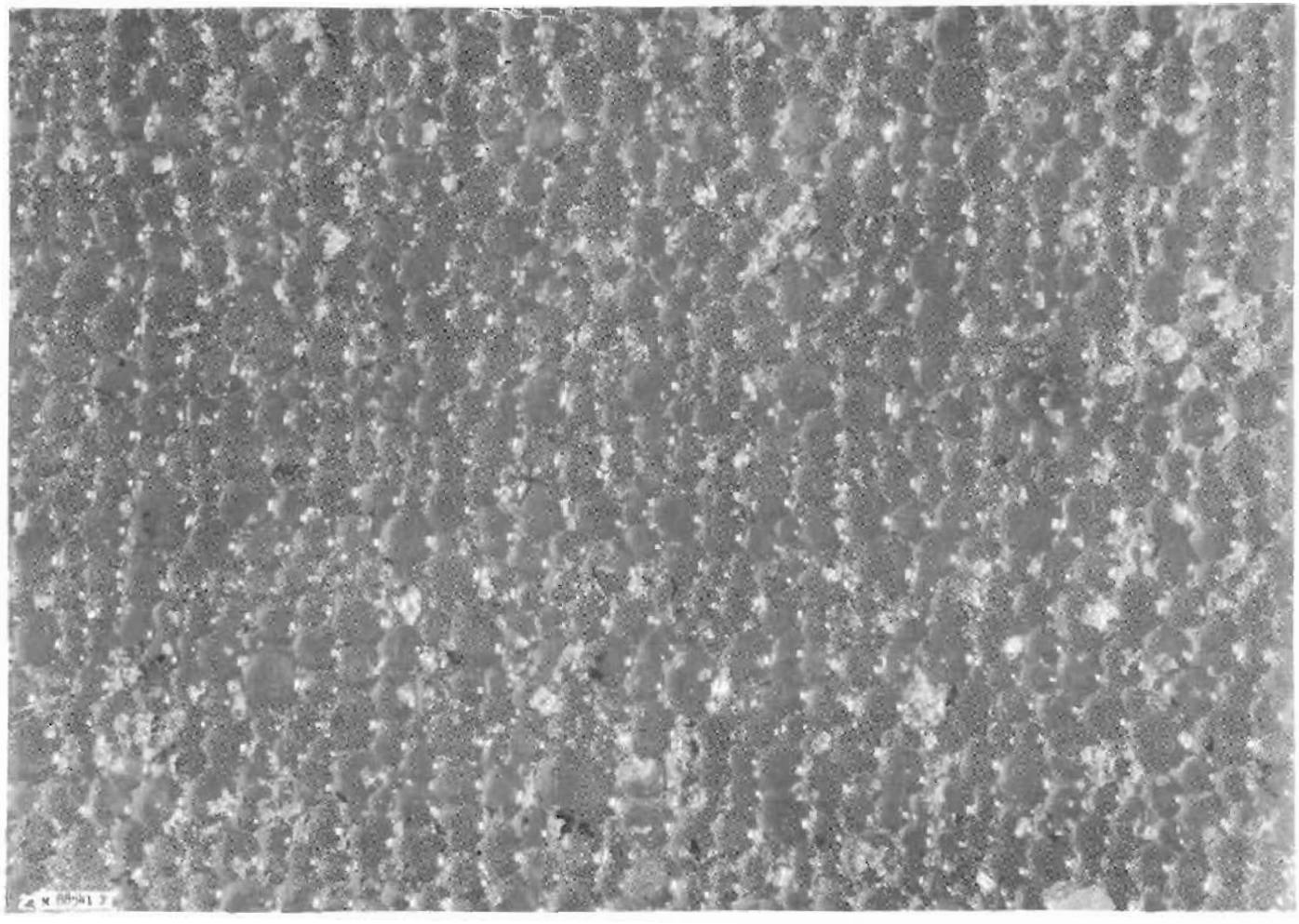

Figure 3.--Photomicrograph of the core surface adjacent to a facing in a sandwich panel with a core of alkyd isocyanate foam, showing failure in the first layer of cells. The photograph is of the bottom plate of specimen No. F9 - 1 - 10, figure 2.

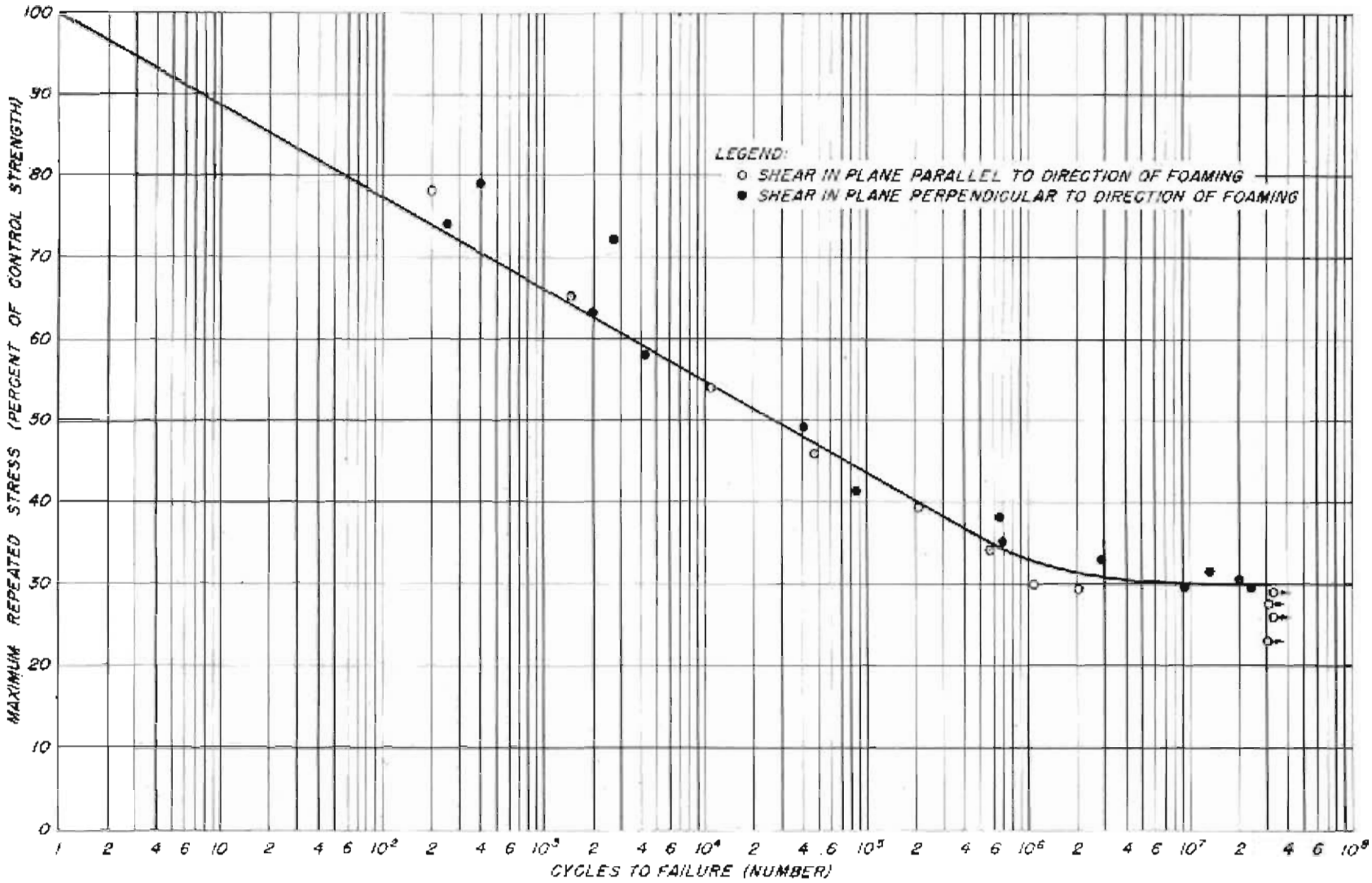

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Figure 4.--S-N curve for sandwich material with a core of alkyd isocyanate foam and facings of glass-fabric laminate, tested in shear. Ratio of minimum to maximum stress (range ratio) was 0.1.

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