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Report No. 8926-159

Material - Magnesium - AZ91 Casting

Evaluation of Non-Destructive Inspection Procedures

P. W. Bergstedt, H. C. Turner, W. M. Sutherland

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Evaluation of Non-Destructive Inspection Procedures

Abstract:

The multi-ribbed framework for the F-102A airplane speed brake door is an AZ91 magnesium alloy casting about 2-1/2 feet wide by 4-1/2 feet long. This complex casting, which essentially is a lattice of thin-walled ribs, is heat treated and aged prior to end use. Since excessive porosity was encountered with a large number of castings, correlations of the casting strengths with the results of dye-penetrant and radiographic inspection were required. As a result of comparisons of tensile strength data with dye-penetrant and radiographic inspections, the following conclusions were drawn: (1) dye-penetrant inspection is inadequate for determining acceptable limits of casting porosity; and (2) x-ray ratings correlated very well with tensile test results. Radiographic inspection thus was considered the more reliable inspection method.

Reference: Bergstedt, P. W., Turner, H. C., Sutherland, W. M.,
"Speed Brake Casting, 8-73673, Evaluation of,"
General Dynamics/Convair Report MP 56-216, San Diego,
California, 13 March 1957. (Reference attached).



ANALYSIS

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REPORT NO. 56-216
SPEED BRAKE CASTING, 8-73673
EVALUATION OF

INTRODUCTION:

Part No. 8-73673 is a multi-ribbed framework for the speed brake door of the F-102A. The casting is roughly 2 1/2 ft. wide and 4 1/2 ft. long; it is cast from AZ91 magnesium alloy and subsequently heat treated and aged. Although the complexity of the problems associated with the fabrication of these castings can be readily appreciated, many of the parts received at Convair were found to possess an inordinate amount of porosity. This report describes the evaluation tests which were made on three (3) of the castings.

OBJECT:

To determine the efficiency of dye-penetrant and radiographic inspection as methods of rating casting quality.

CONCLUSIONS:

The tensile tests of specimens cut from the castings led to the following conclusions:

1. Dye-penetrant inspection cannot be considered an adequate method of determining the acceptable limits of casting porosity.
2. As anticipated, X-ray ratings correlated very well with tensile test results. Radiographic testing is much more trustworthy than dye-penetrant examination as a non-destructive test of such porous materials.

PROCEDURE:

Three castings, identified by X-ray No., were included in this investigation. After dye-penetrant examination, rough specimen outlines were scribed on the metal in areas which exhibited varying amounts of dye "bleed-out". The parts were then cleaned and marked for sampling as shown in Figures 1, through 3. In all, twenty-nine specimens were removed from the three castings; No. 18 proved to be too small for test purposes and was discarded.

The coupons were machined to standard 0.5-inch gauge width, but the original surfaces were not disturbed along the flat sides of the samples. In the instances where adjoining ribs entered the gauge section, the ribs were simply cut off outside the fillets.

The samples were then inspected and rated by the Process Control Department. The dye-penetrant method requires approval or rejection by an experienced inspector. Photographs of all of the coupons are shown in Figures 4 through 10; the pictures were taken shortly after the dye-penetrant examination and with the developer coating still intact.

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PROCEDURE: (Continued)

The grading system employed in the X-ray ratings is based upon a series of filmed standards prescribed by ASTM Standard E98-53T. According to this comparison type of evaluation, Grade 1 would be free of defects, Grade 2 acceptable, Grade 3 acceptable but questionable, and Grade 4 would be rejectable. (This type of procedure enjoys wide-spread usage).

No X-rays were taken of coupons removed from the static-test casting - specimens 18 through 29.

Tensile testing was accomplished by the Physical Test Section using the 12,000 lb. Tinius Olsen Machine.

From the broken tensiles, small sections were then cut from the fracture areas and grouped in plastic mounts for polishing - two or three samples per mount. In each case the prepared surface represented an internal portion of the sample, perpendicular to the fracture, and extending 1/4" to 3/8" from the fracture.

RESULTS AND DISCUSSION:

The tensile properties and inspection ratings of the coupons are shown in Table I. The "Correlation" column was based upon an overall appraisal of ratings vs. actual properties for each specimen.

The dye-penetrant technique proved to be useful for rejecting material, but the method could not be used in a positive sense - too many spongy samples were apparently acceptable.

Radiographic inspection was much more reliable as a means of estimating acceptable limits of micro-shrinkage. Since X-rays can detect internal voids which are not connected to the surface, the advantage of this method in applications of this type is readily understood and accepted. It is unfortunate that the X-ray examination did not include the group of specimens from the static-test casting.

A study of the photomicrographs disclosed many regions of localized porosity and/or mechanical tears. Each photograph represents only a small portion of a particular sample and often tends to exaggerate the extent of the defects. The economical practice of placing more than one sample in a single plastic mount led to considerable difficulty in producing an even polish on the relatively soft magnesium samples. Consequently, only one photomicrograph is included in the report for each of the described conditions (Figures 11 through 17).

NOTE: This report was prepared from data recorded in Laboratory Record Book No. 910.

TABLE I. MECHANICAL PROPERTIES & INSPECTION RATINGS OF TENSILE SAMPLES FROM AZ 91-Mg CASTINGS.

TABLE 1. MECHANICAL PROPERTIES & INSPECTION RATINGS OF TENSILE SAMPLES FROM A2-VI TITAN CASTINGS.									
SPECIMEN No.	MECHANICAL PROPERTIES		DYE PENETRANT RATING ACCEPTABLE	RADIOGRAPHIC RATING			METALLURGICAL RATING (EXAM. BY MICROSCOPY)	COLLAPSE RATING (EXAM. BY PULL)	
	F _{TS} KSI	F _{TS} PSI 2-in. gauge		GRADE 2	GRADE 3	GRADE 4			
13	11,130	12,280	1.5			X	SEVERE	Good	
28	13,590	13,900	2.5			X	MODERATE	Poor	
2	10,370	14,330	1.5				SEVERE	Good	
27	13,250	14,500	2.0				"	"	
21	11,100	15,100	3.5				"	"	
17	10,300	15,200	2.0			X	"	"	
5	13,900	15,800	— *			X	"	"	
1	13,600	17,200	2.0			X	"	"	
26	16,600	17,900	2.0				MODERATE - SEVERE	Poor	
20	15,500	18,700	2.0				MODERATE	"	
23	13,900	18,900	2.0				SEVERE	"	
25	16,400	19,400	2.5			X	SEVERE (LOCALIZED)	Good	
6	13,200	20,600	2.5				MODERATE - SEVERE	Fair	
11	17,400	21,200	0.5 *				SEVERE (LOCALIZED)	Good	
24	17,300	21,400	2.0				MODERATE (TORN)	Poor	
12	17,990	21,910	2.5			X	MODERATE - SEVERE	Fair	
7	15,900	23,000	1.0			X	MODERATE (TORN)	"	
22	16,300	23,000	2.0			X	MOD. SEV. (NOT LOCAL)	Good	
3	17,300	24,100	0.5			X	MODERATE (TORN)	"	
10	20,100	24,300	2.0				SLIGHT (TORN)	"	
4	17,300	27,900	1.5				"	"	
16	17,300	28,500	1.0 *				MODERATE (LOCAL)	"	
8	18,600	29,100	— *				"	"	
18	18,800	31,100	2.5			X	"	"	
15	17,100	31,900	3.5			X	"	"	
14	18,100	33,100	3.5			X	"	"	
9	20,200	33,600	4.0			X	"	"	
23	17,400	34,600	2.0				"	"	
* FOR TESTING TECHNIQUE - GRIP NOT RIGID									

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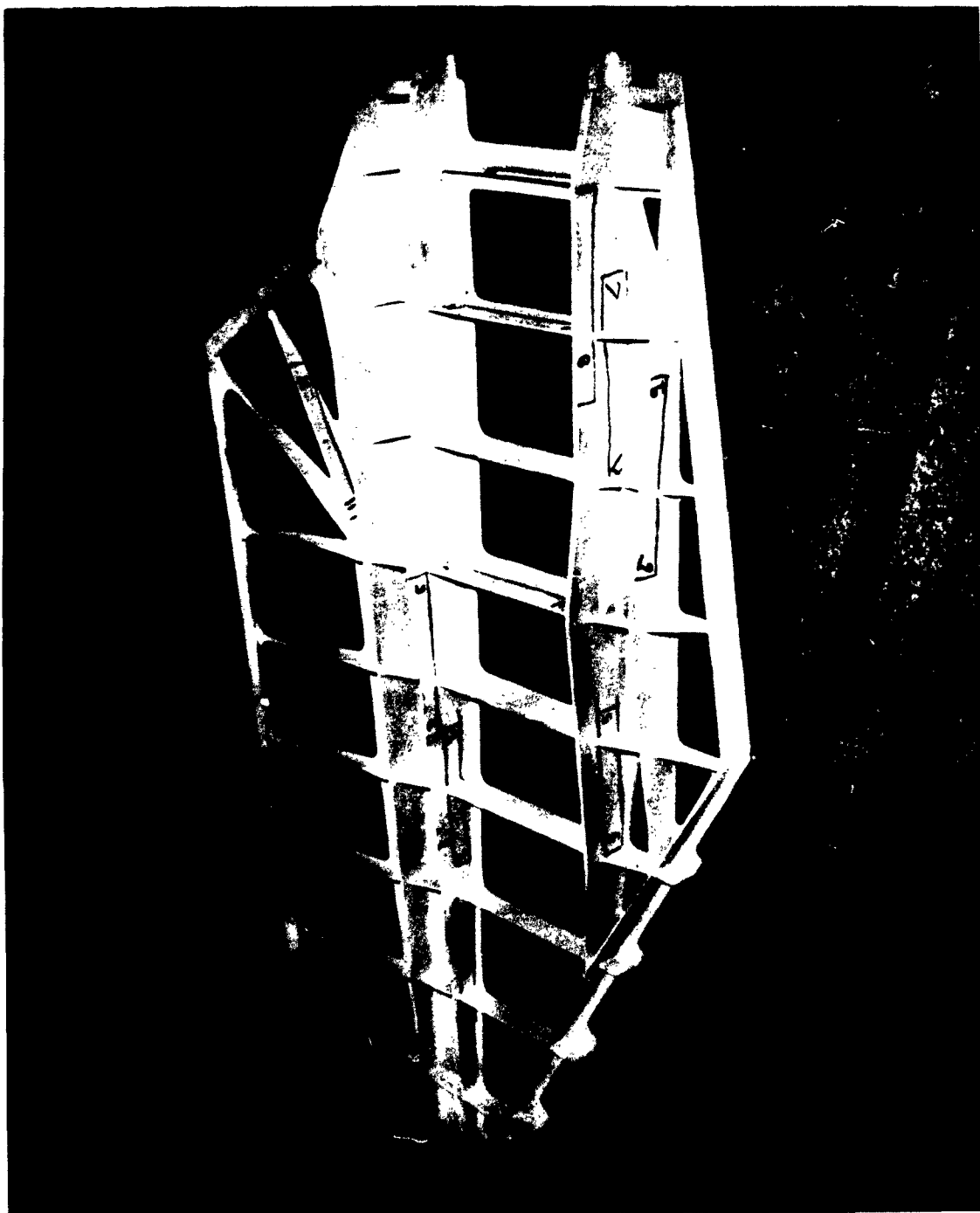


FIGURE 1. PART NO. 8-73673, X-RAY NO. H7315-2 (COUPONS 1-11)

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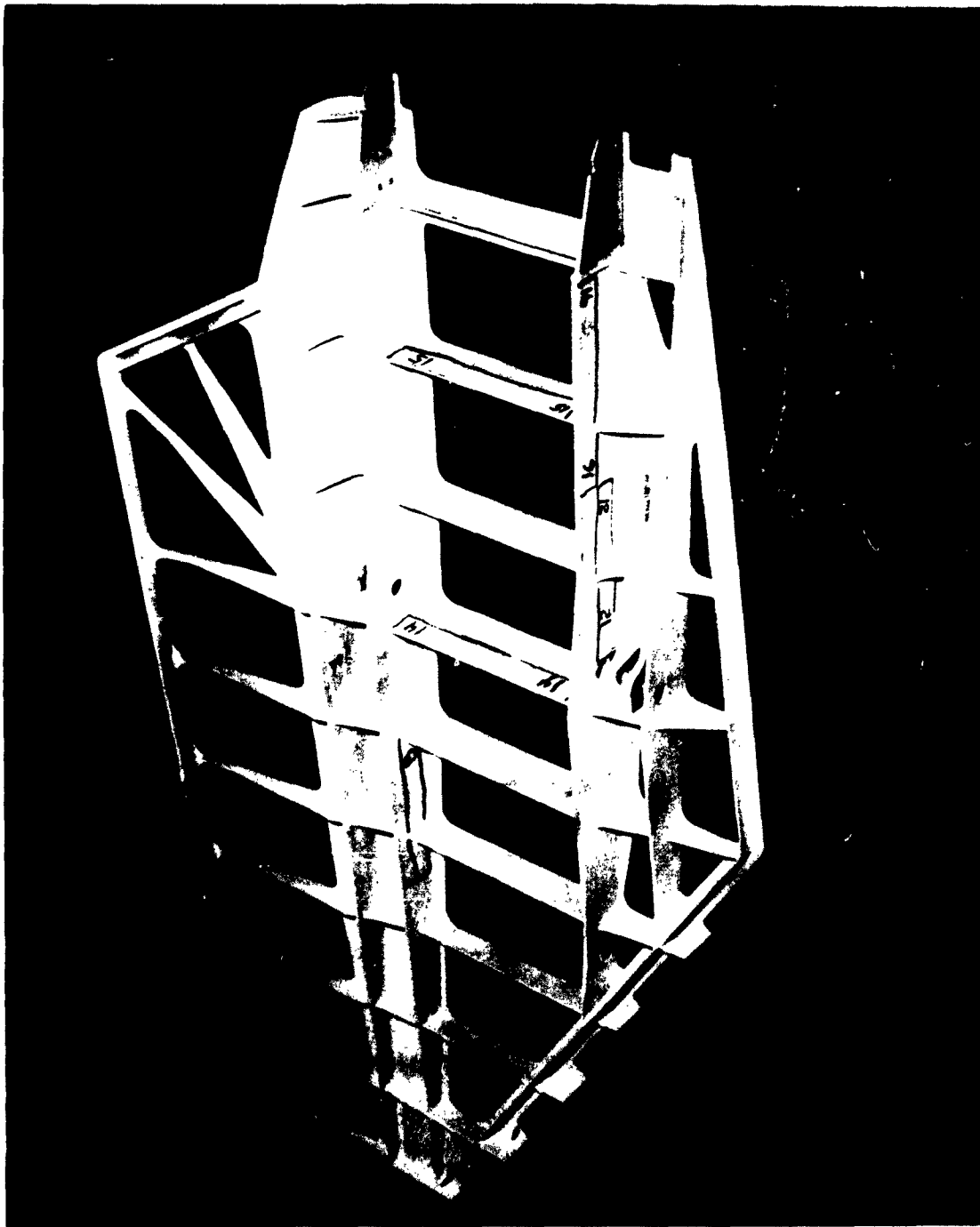


FIGURE 2. PART NO. 8-73673. X-RAY NO. H7315-1 (QUORNS 12-17)

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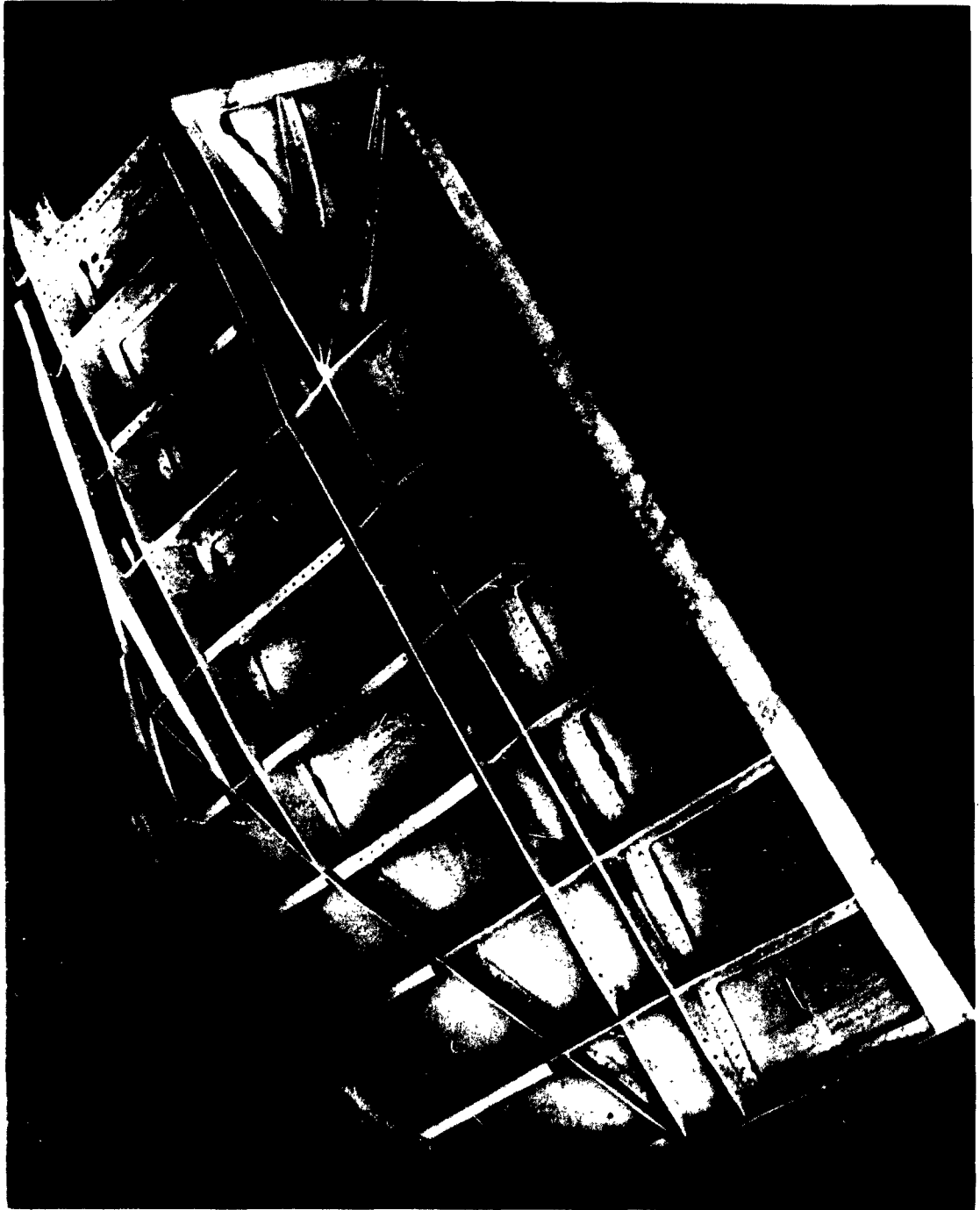


FIGURE 3. STATIC-TEST CASTING, X-RAY NO. H7316-3 (COUPONS 18-29)

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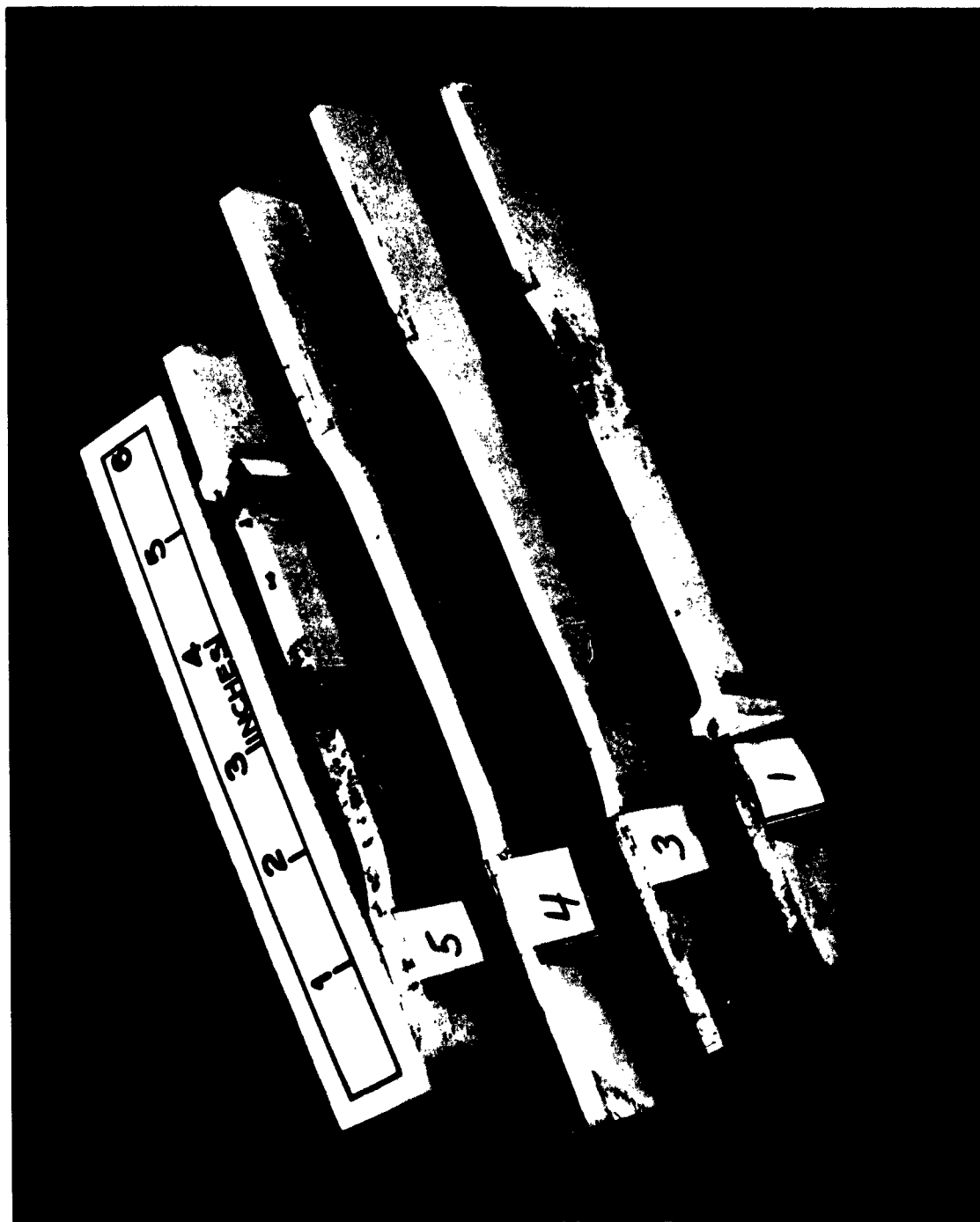


FIGURE 4. COUPONS 1, 3, 4, & 5. (SHOWING DYE INDICATIONS)

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FIGURE 5. COUPONS 7-11 (SHOWING DYE INDICATIONS)

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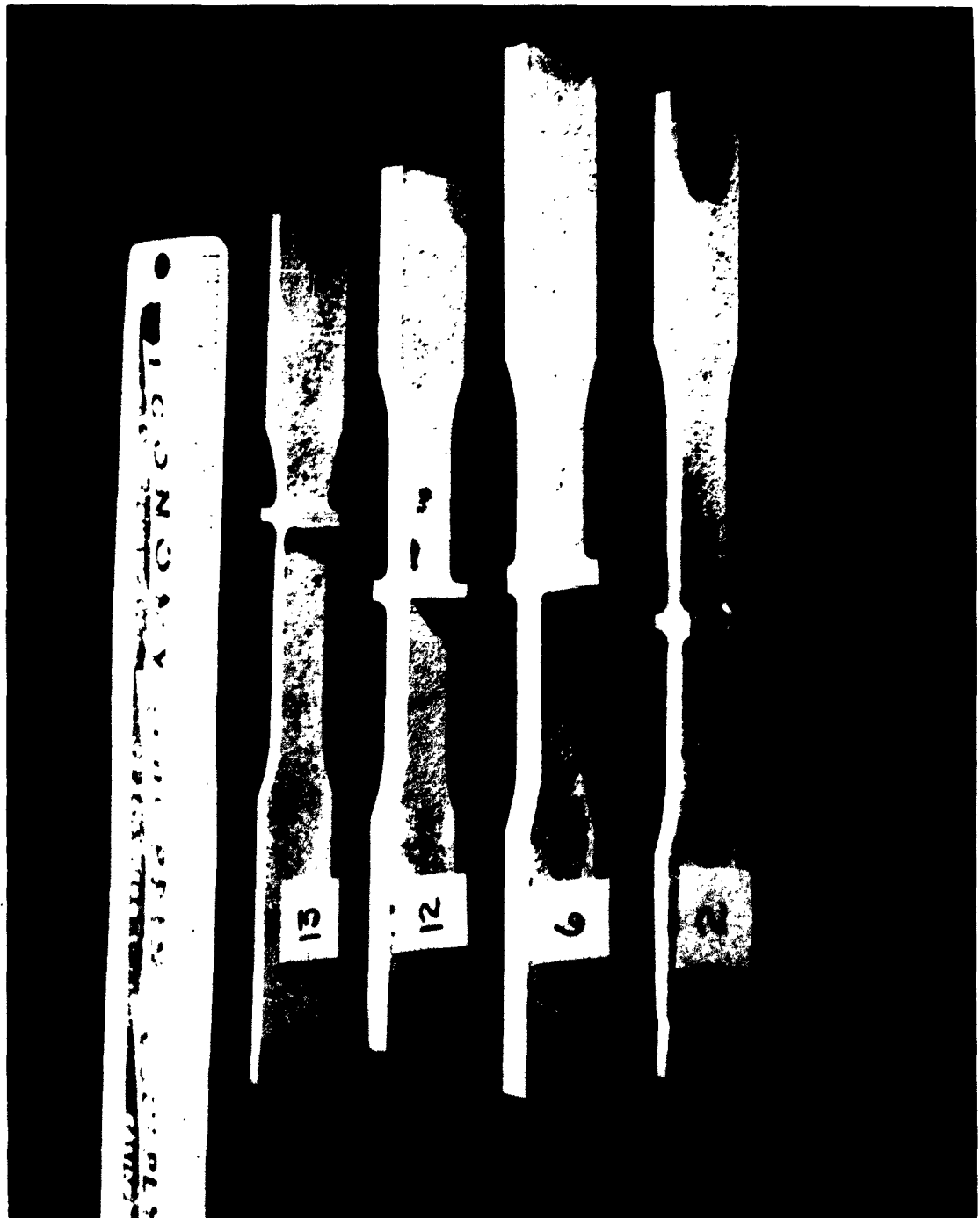


FIGURE 6. COUPONS 2, 6, 12, & 13 (SHOWING DYE INDICATIONS)

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FIGURE 7. COUPONS 14-17 (SHOWING DYE INDICATIONS)

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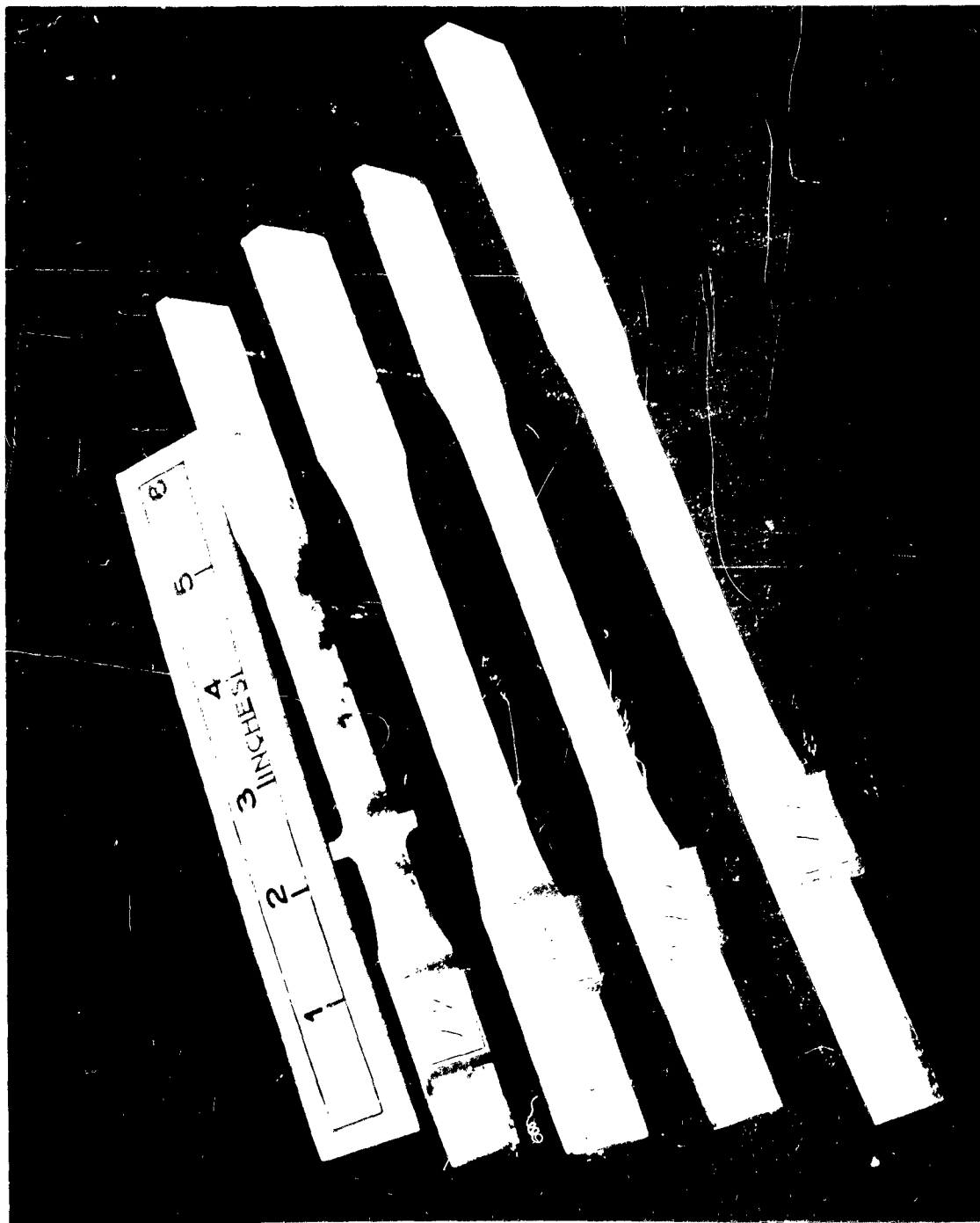


FIGURE 7. COUPONS 14-17 (SHOWING DYE INDICATIONS)

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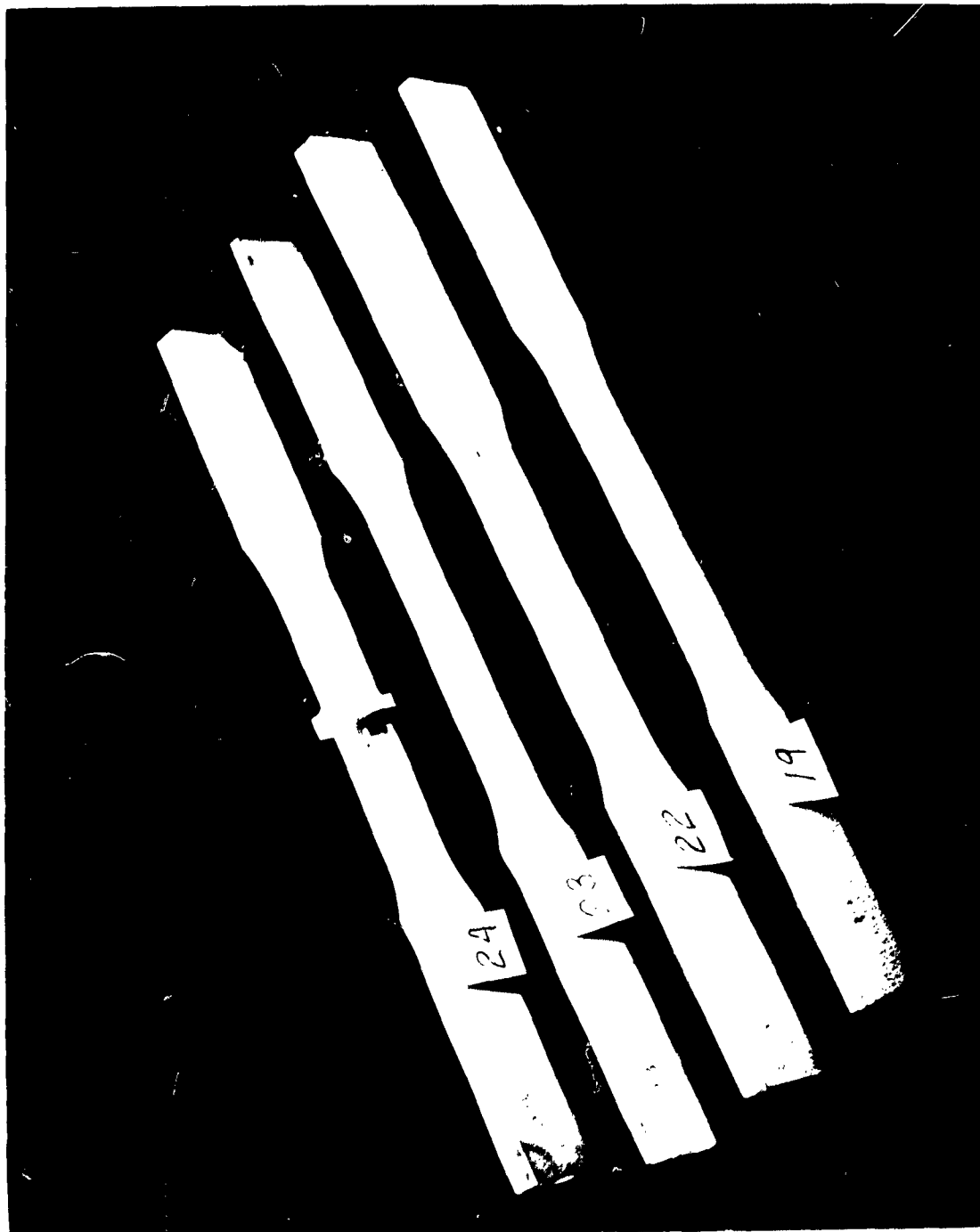


FIGURE 8. COUPONS 19, 22, 23, & 24 (SHOWING DYE INDICATIONS)

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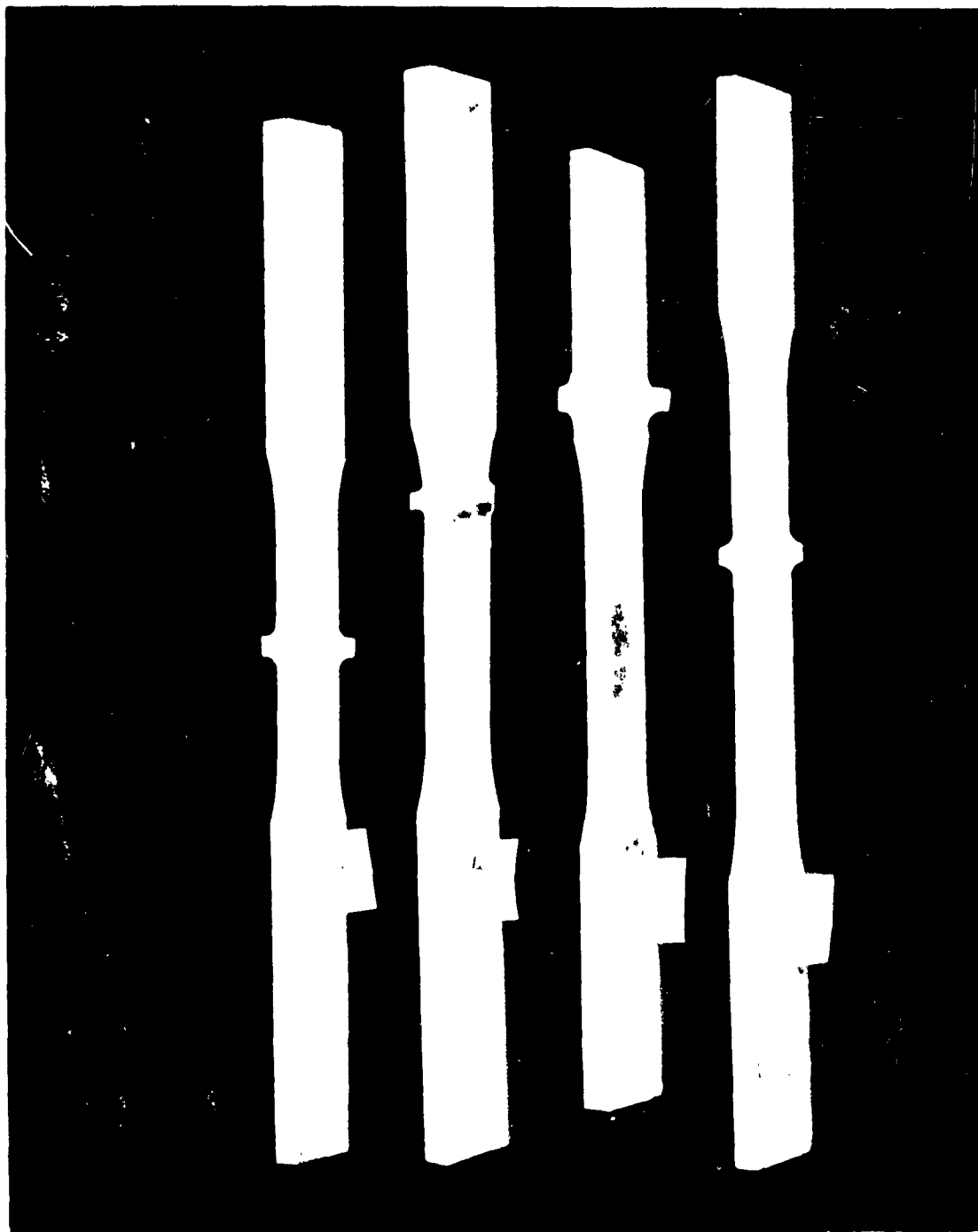


FIGURE 9. COUPONS 20, 21, 25, & 26 (SHOWING DYE INDICATIONS)

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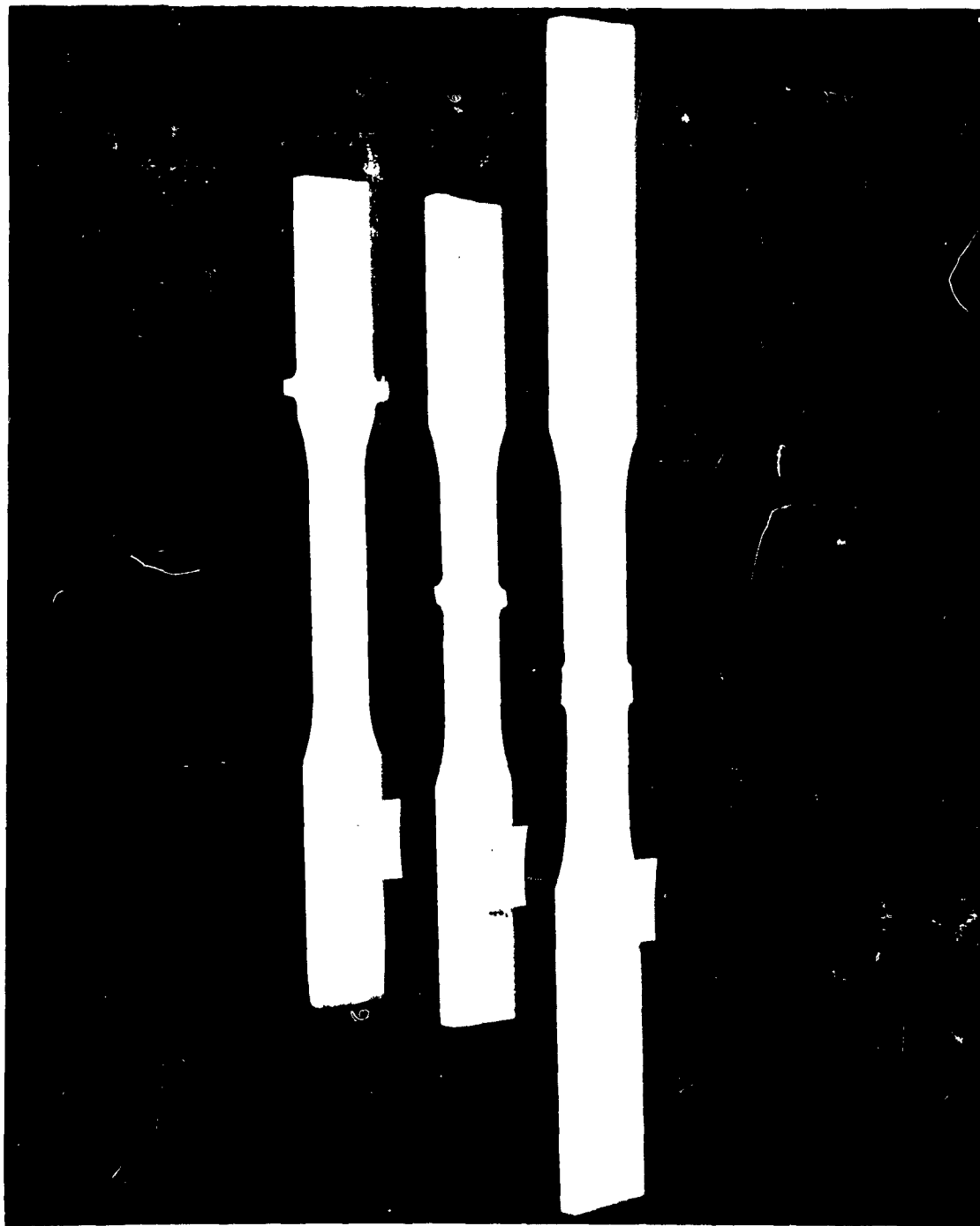


FIGURE 10. COUPONS 27-29 (SHOWING DYE INDICATIONS)

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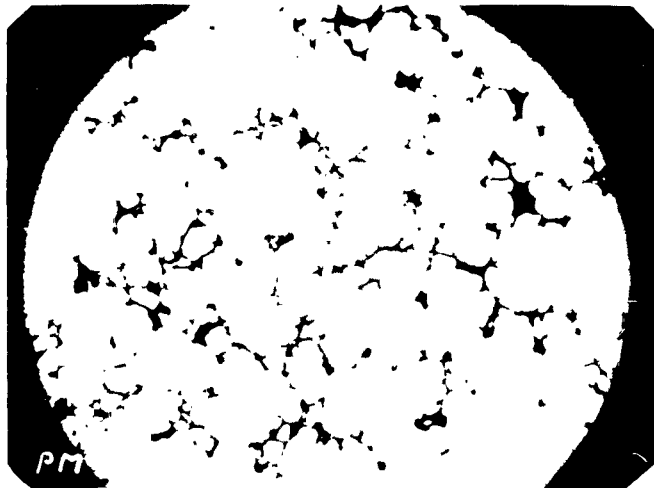


FIGURE 11. "SEVERE" SHRINKAGE POROSITY (SPEC. No.13)

MAG: 100X UNETCHED



FIGURE "MODERATE TO SEVERE" CONDITION (SPEC.No.7)

MAG: 100X UNETCHED

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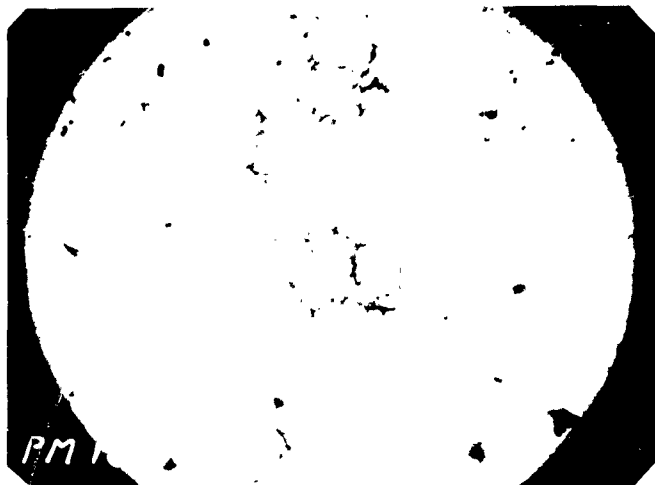


FIGURE 13. "MODERATE" CONDITION (SPEC. No. 28)
MAG: 100X UNETCHED



FIGURE 14. "SLIGHT" CONDITION (SPEC. NO. 14)
MAG: 100X UNETCHED

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FIGURE 15. "SEVERE-LOCALIZED" CONDITION (SPEC.NO. 24)

MAG: 100X

UNETCHED



FIGURE 16. "MODERATE-LOCALIZED" CONDITION (SPEC.NO. 9)

MAG: 100X

UNETCHED

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FIGURE 17. "TORN" CONDITION (SPEC. NO. 10)

MAG: 100X UNETCHED