

ADHESIVES FOR AEROSPACE

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INTRODUCTION

The industry is hereby challenged to integrate adhesive technology with the total structure requirements in light of today's drive into automation/mechanization. The state of the art of adhesive technology is fairly well meeting the "needs" of the structural designers, the processing engineer, and the inspector, each on an individual basis. But the total integration of these needs into the "factory of the future" is the next collective hurdle to be achieved. Improved processing parameters to fit the needs of automation/mechanization will necessitate some changes in the adhesive forms, formulations, and chemistries.

ELEMENTS OF BONDING

In addressing the needs of adhesives for the aerospace industry, the entire structure to be bonded must be considered. A bonded joint is only as good as the weakest element of the total. Figure 1 shows the elements of a typical bonded joint in an aircraft bonded structure. The adherend, surface treatment, primer, adhesive, and core (if sandwich) plus the processes used all must be considered. Figure 2 presents the state of the art for each of these adhesive bonding elements over the past two and one-half decades.

The Lockheed-Georgia Company has applied bonded structure on aircraft, starting 32 years ago on the C-130 (Figure 3)⁽¹⁾. As seen in this figure, the applications were for fairings, secondary structure and some control surfaces. The JetStar (C-140) aircraft seen in Figure 4, designed in 1959, utilized a limited amount of bonded structure similar to the C-130. The C-141 (Figure 5) followed the C-130 by ten years, in 1962, and used approximately 10,000 square feet of bonded honeycomb structures, considerably more than the C-130. These included several primary structures plus fairings, leading edges, control surfaces, wing tips, landing gear doors, aft cargo doors and other secondary structure. The C-5A aircraft (Figure 6) used approximately three times as much bonded structure as did the C-141,

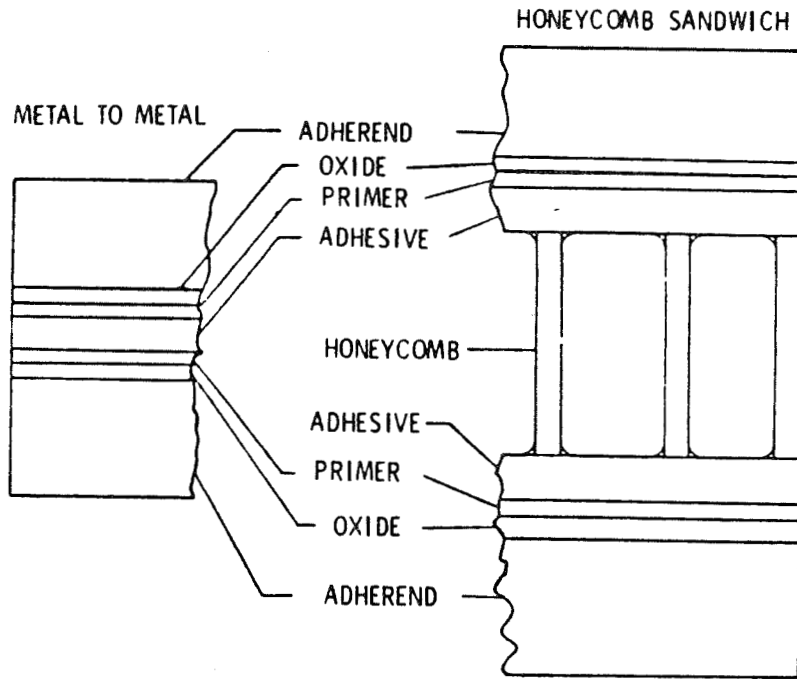


Figure 1. Elements of Bonding

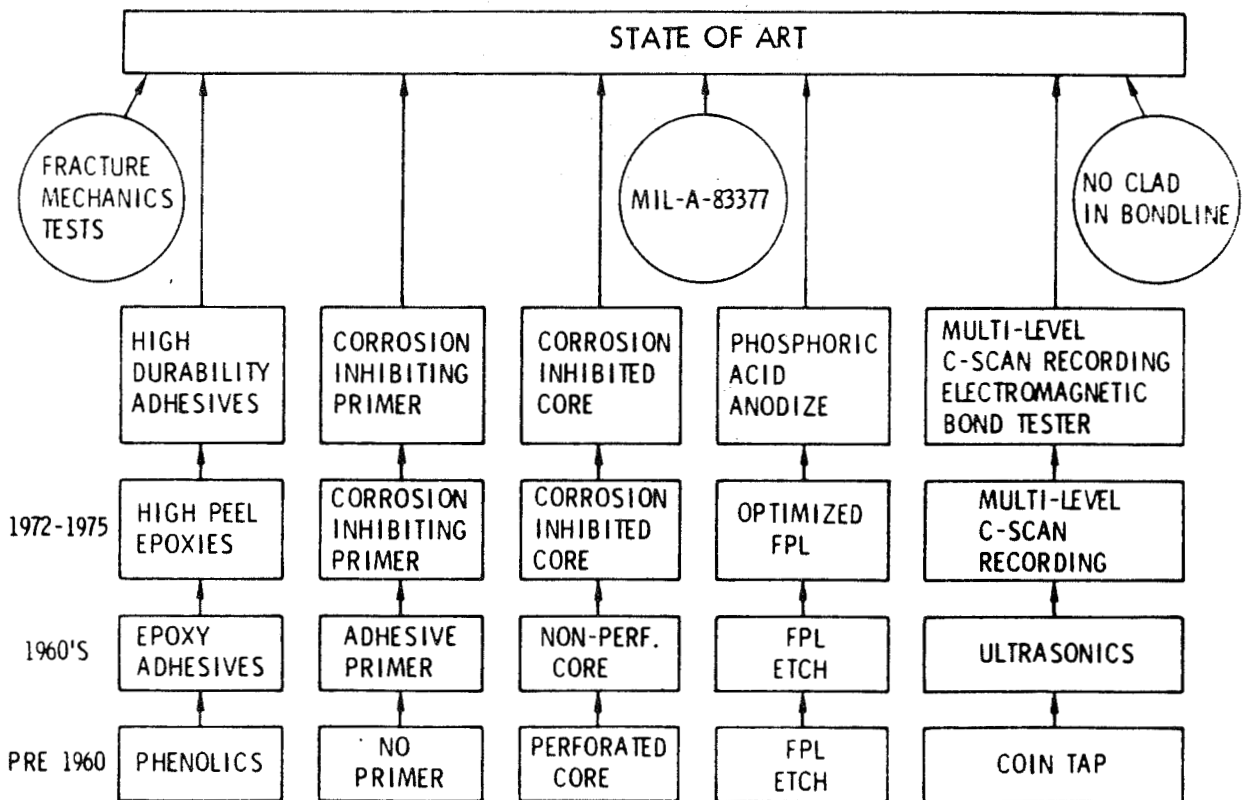


Figure 2. State of Art Bonding Technology

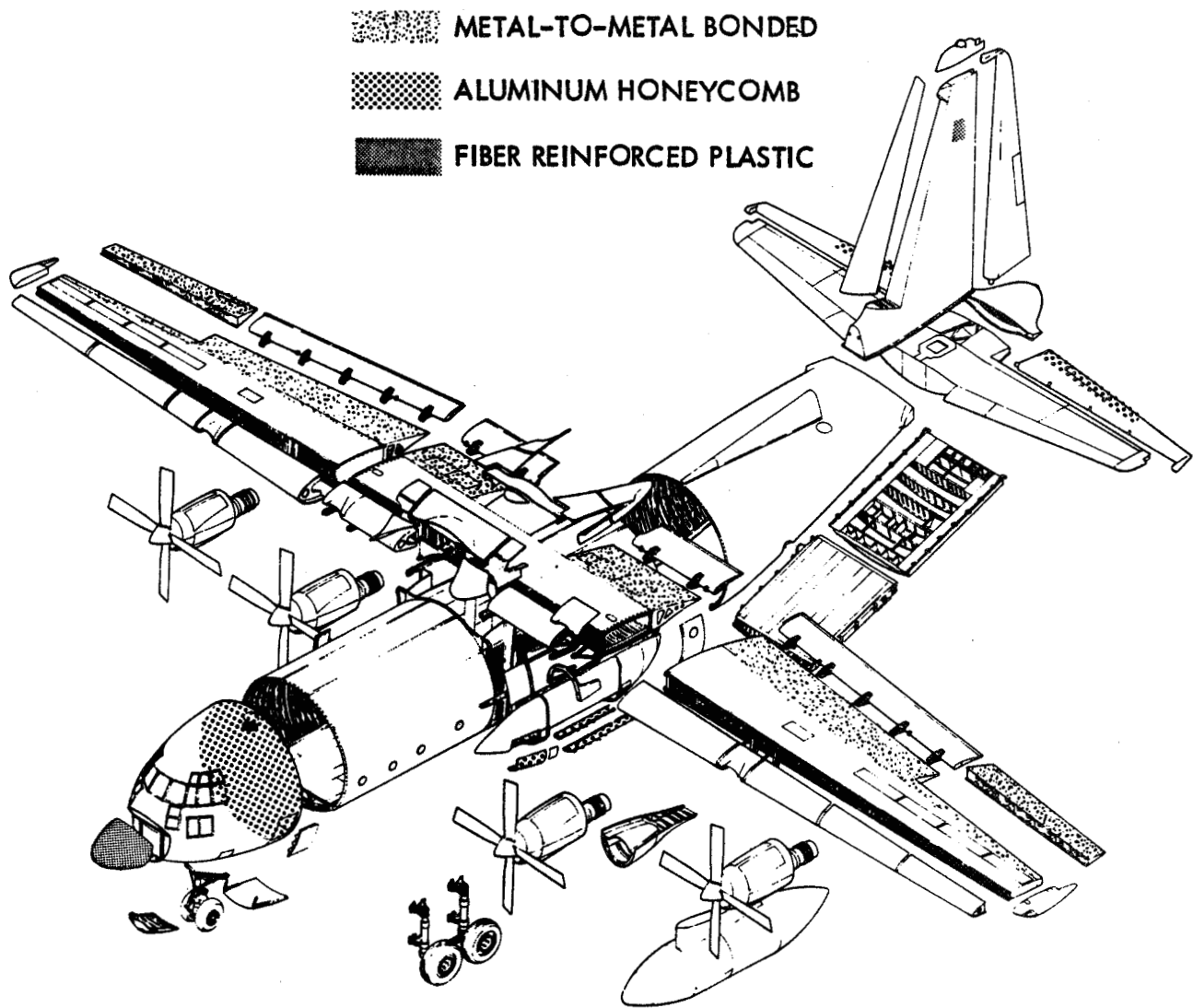


Figure 3. C-130 Bonded Structure

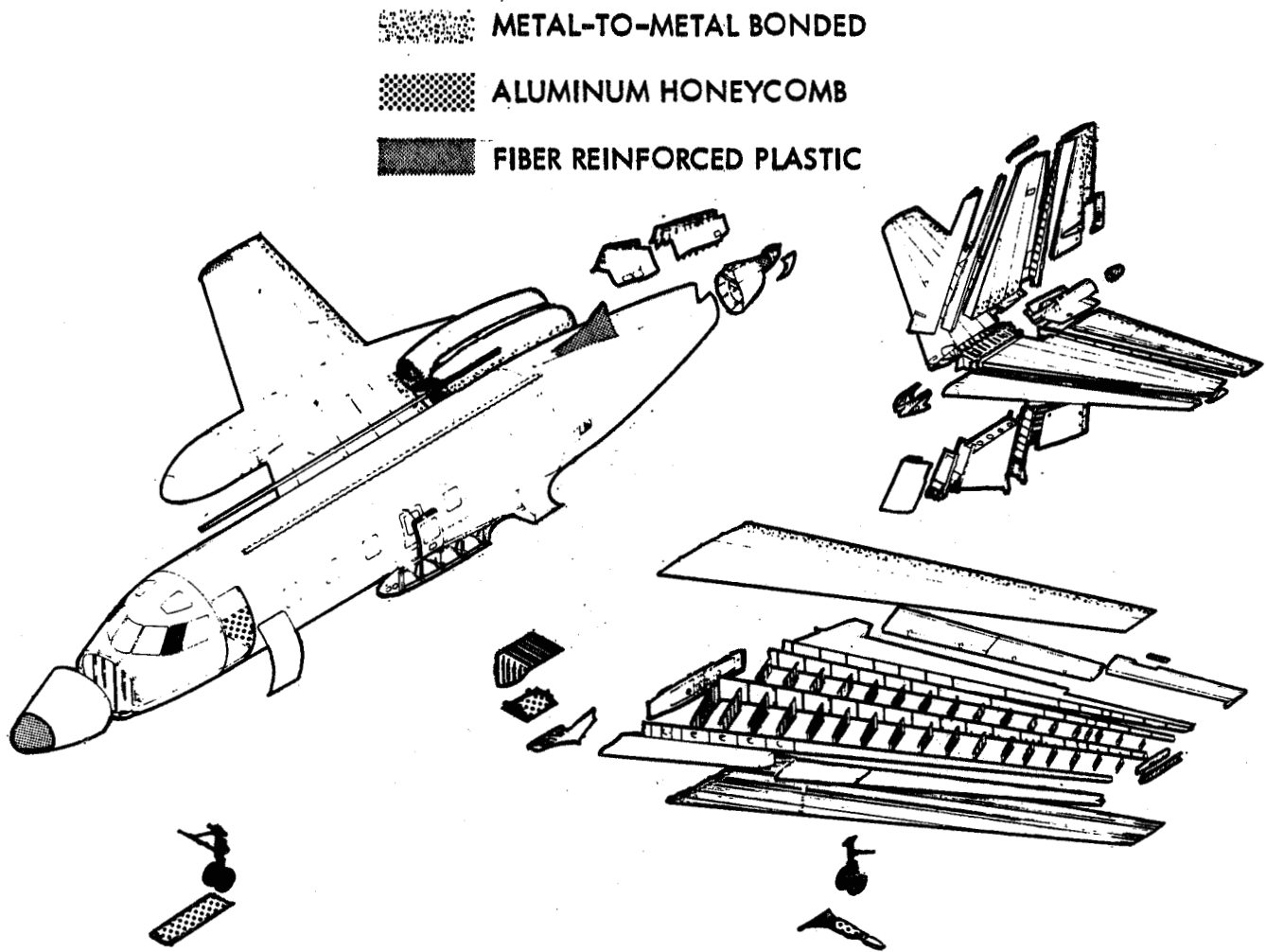


Figure 4. JetStar Bonded Structure

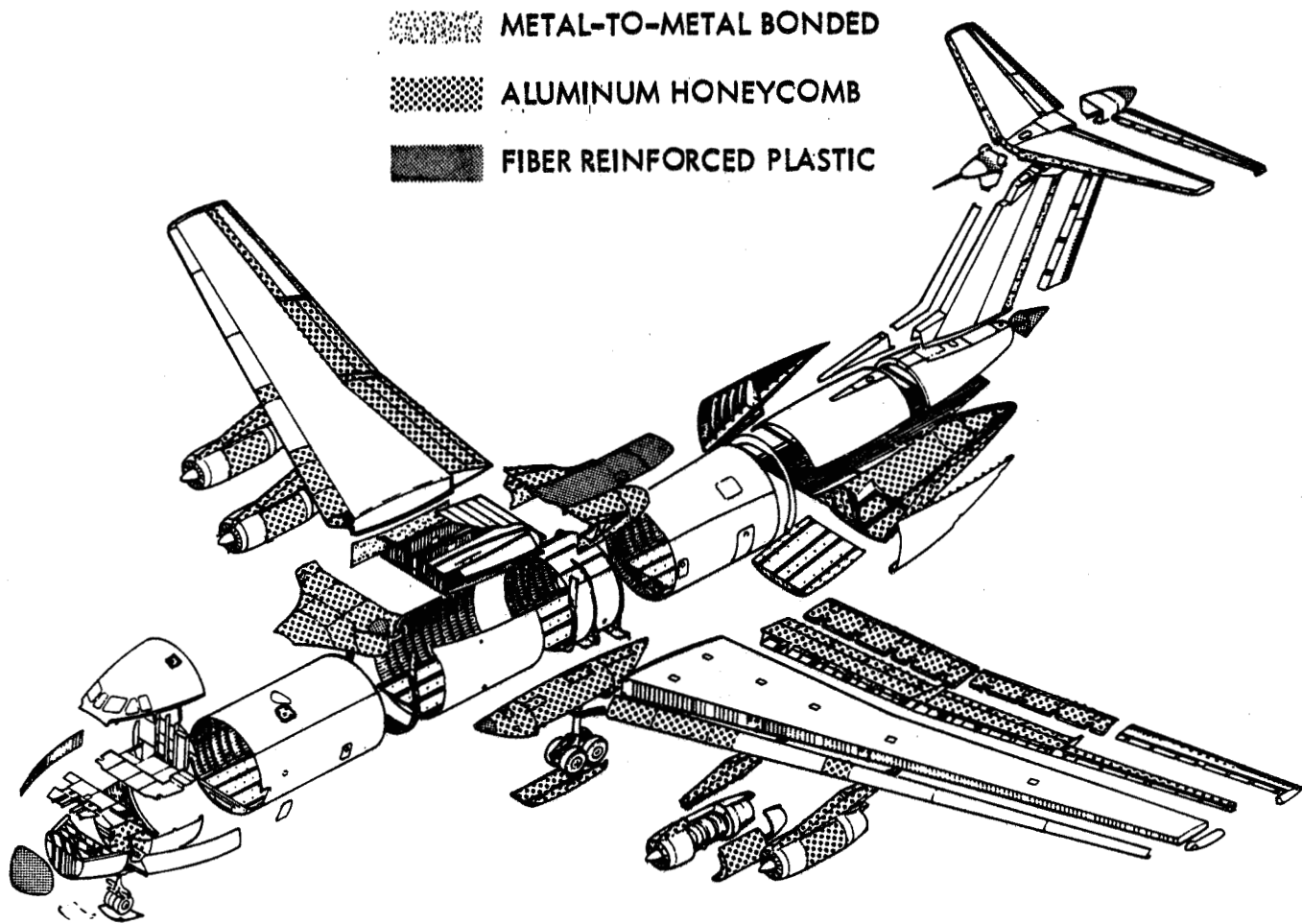


Figure 5. C-141 Bonded Structure

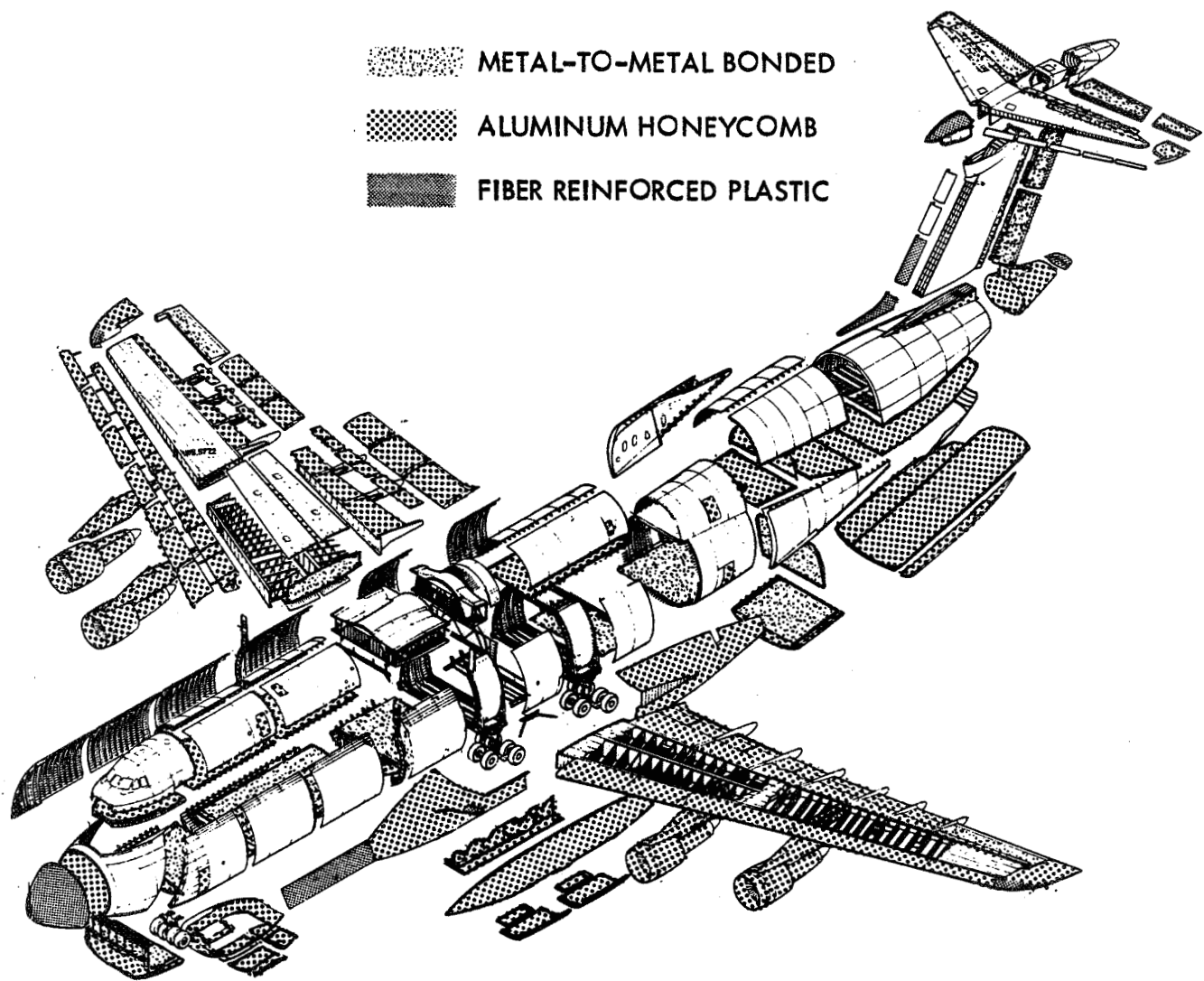


Figure 6. C-5 Bonded Structure

and went into production in 1966. Primary structure that was bonded extended to underfloor bulkheads, cargo floor, troop compartment floor, and pressure bulkheads. A comparison of the honeycomb and metal-to-metal bonded structure on the four different aircraft is shown in Figure 7. These four aircraft, covering over three decades, progressed with adhesive and surface preparation developments up to the presently used PABST (Primary Adhesive Bonded Structure Technology) type adhesives and phosphoric acid anodize on C-130 spares at the current time (1,2).

For most of aerospace's bonding needs, aluminum and composites make up the majority of substrates to be bonded. The surface treatments most widely used for aluminum are Optimized Forest Products Laboratory (OFPL) etch, unsealed chromic acid anodize, and phosphoric acid anodize. The surface morphology of these treatments (the oxide produced) is improved by the use of corrosion inhibitors in adhesive based primers (3). Much work has been accomplished on new systems currently being used. Most of the current primers are solvent carried, but environmental pollution regulations are increasingly requiring no solvent emission and as such are driving our needs toward aqueous based primers for either spray or electro-deposited processes (4). Several companies are working on electro-deposited primers to meet these needs (5).

Composite substrates (the resin matrix composites) need fresh resin surfaces exposed for wetting by the adhesive or adhesive primers. Either peel ply or grit blast process are used to provide surfaces that are receptive to adhesive materials. Primers will enjoy increased use on composites for (a) surface protections against contamination during shop handling and storage and (b) promotion of improved wetting of the cured composite surface by the adhesive.

The adhesive films available to all of us today are vastly improved from a decade ago (2), but there is an ever-increasing need for better toughness along with hot-wet strength property improvements. At the same time, we need to improve the economics of processing by lower cure temperature, longer out time, and less sensitivity to storage conditions and cure pressures (private conversations with S. Westerback, Grumman Aerospace Corporation; E. House, Boeing Company; M. Williams, GD/Ft. Worth; J. Morrow, Rohr/Ind; M. Lindsey, Lockheed-Georgia Company; B. Silverman, PRC, Inc.). The corrosiveness of by-products from the cure process needs further attention to ensure that the adhesive materials are neutral from a corrosion standpoint.

The overall adhesive bonding processes and the manufacturing technologies used to produce the finished assembly need consideration at the time of structure design. Advanced bonding techniques have not yet been fully integrated into bonding facilities, as suggested by Figure 8. The adhesive bonding and composite fabrication factories of the future will encompass much automation. These techniques will encompass many mechanized systems taking the human guesswork and variables out of the process. Increased emphasis will be placed upon material consistency, narrower tolerances, and instrumental analysis means of verification of both the material chemistry and its optimum processing (6). Adhesives suppliers will need to

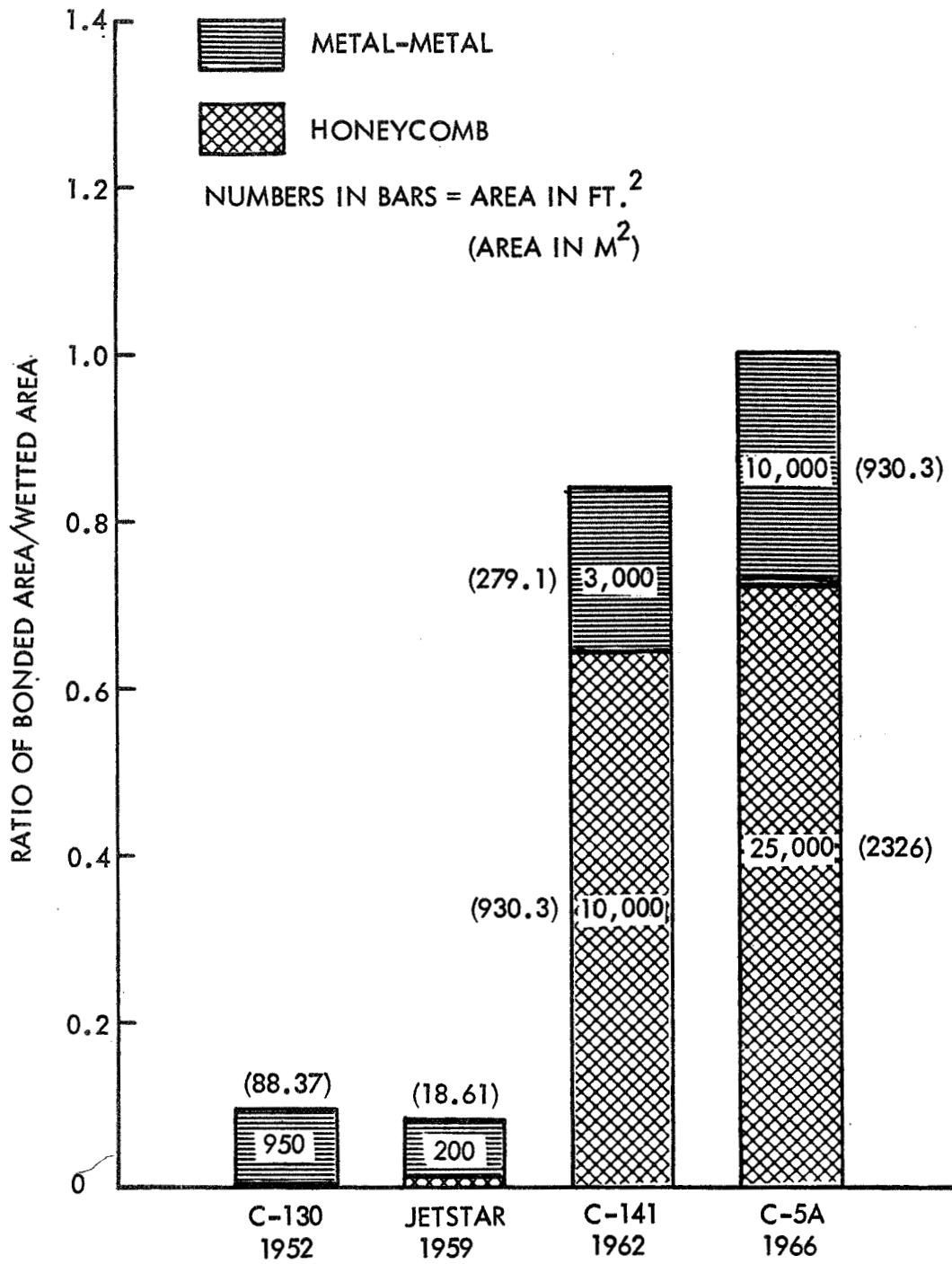


Figure 7. Ratio of Bonded Area to Aircraft Wetted Area

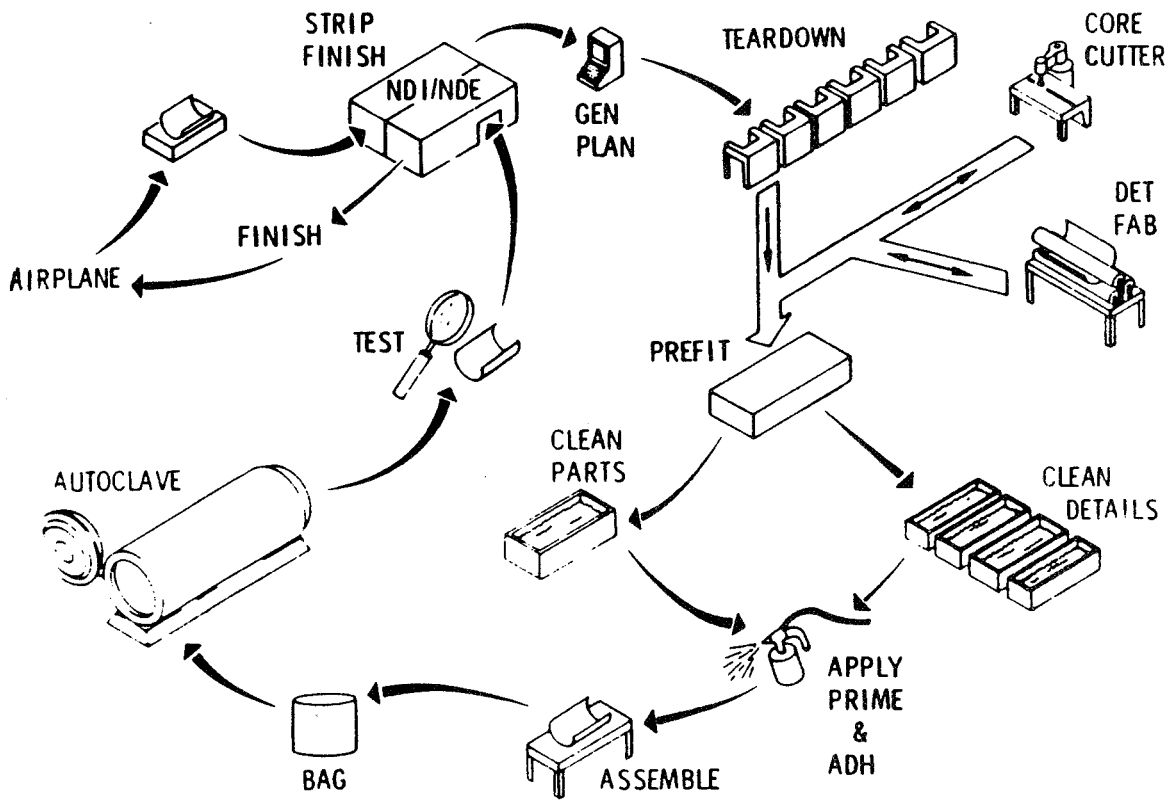


Figure 8. Preliminary "To Be" Concept - Honeycomb Banding Center

work ever more closely with structure designers, factory layout engineers, process engineers and quality assurance personnel in the formulation and manufacture of new materials.

The use of structural adhesive bonding as the primary means of sealing fuel cell structures has been well demonstrated by the F102, F100, 880 and 990 aircraft. Advanced made in adhesives and surface treatments make this approach even more desirable today. Much work is being concentrated on integrating all of the required elements to achieve the highest degree of producibility with the latest technology in adhesively sealed, bonded/fastened fuel cell structure both in fighters (as is being accomplished on the F16), and in future transport applications.

CONCLUSIONS

- (1) Adhesives have, for the most part, kept up with the "needs" of the aerospace industry, normally leading the rest of the industry in developments.
- (2) The "wants" of the aerospace industry still present a challenge to encompass all elements, achieving a totally integrated joined and sealed structural system.
- (3) Better toughness with "hot-wet" strength improvements is desired.
- (4) Lower cure temperatures, longer out times, and improved corrosion inhibition are desired.

REFERENCES

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