Paper Number

Automated Wing Panel Assembly for the A340-600

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ABSTRACT

The Airbus A340-600 wing panel manufacturing system, which entered production in 1999, represents a major milestone for automated aircraft assembly. The new A340-600 system builds upon the success of the E4000 based A320 wing panel assembly system, which was introduced into production three years ago. The new A340-600 system consists of two 440 ft. assembly lines. One produces upper wing skin panels and the second produces lower skin panels. Each line consists of three fully automated CNC controlled flexible fixtures placed end to end serviced by two E4100 CNC assemble machines. Each fixture accepts multiple wing panels and can be automatically changed between the different configurations. Stringers are located and held using clamps mounted to “popping posts”. These posts automatically drop out of the machine path into the floor to provide clearance for complete stringer to skin fastening.

INTRODUCTION

The A340-600 wing panel assembly system is a third generation “in jig” wing panel automated assembly system. Wing panel assembly components such as stringers, panels, splice plates and reinforcings are located and fastened under CNC control in these automated cells. Previous systems consist of a series of dedicated wing panel fixtures lined in a row and serviced by one or more traveling yoke assembly machines (Ref. 1,2). The A340-600 LVER system follows the basis of this concept with the introduction of a new innovative part fixture concept based on the “popping post”. The popping post fixtures provide increased functionality, full automatic set-up and operation all in a smaller footprint than would be required with conventional wing panel jigs.

SYSTEM OVERVIEW

Each A340-600 wing panel surface is comprised of four individual panels as shown in Figure 1. Sixteen individual panels are therefore required per ship set; eight of which are over 100 ft. in length. Conventional fixtures dedicated to single panels would have required significantly more floor space than was available in the existing Airbus facility. The tight floor space constraints and the desire for fully automated operation drove the development of the new flexible “popping post” fixture design. Each fixture accepts two different wing panel assemblies. Further consolidation was achieved by combining panels 2 and 3 into one super panel assembly. (See Figures 2, 3 and 4) The final configuration consists in two parallel lines of three fixtures each. One line provides the functionality for all the upper panels and the adjacent line provides functionality for the lower panels. Since there are important process variations between the two surfaces, this separation makes manufacturing sense.

Two E4100 traveling yoke assembly machines service the three fixtures. Since there are more fixtures than machines, at least one fixture is always free to be loaded or unloaded thereby minimizing machine downtime. The E4100 is a second-generation five-axis dual trunnion yoke machine. The solid yoke machine allows complete five-axis capability within the wing panel envelope while maintaining precision alignment between the skin and stringer side heads. Process capability includes slug rivet and Lockbolt installation, with and without coldworking. The E4100s ride on parallel 440 ft. long machine beds, which straddle the fixtures. Detail parts are loaded into the jig and the E4100 machines installs permanent fasteners. In addition to the significant reduction of floor space, the popping post fixture design, when used in conjunction with the E4100 machine, provides fully automated operation. Similar to previous “in jig” wing spar systems such as ASAT3 and ASAT4 (Ref. 3), these wing panel fixtures can be completely controlled from the assembly machine CNC.

PANEL DEFINITION

Proper configuration of contoured aerodynamic wing surfaces is critical to the performance of the aircraft. Metallic wing surfaces are typically defined in panel build jigs by wrapping either formed or unformed skins around fixtured stringers. Stringers are clamped into the proper orientation against precision located index surfaces. The tightly control panel machining process insures that the desired external surface contour is maintained.

The final wing surface contour is ultimately defined upstream of the panel build process by the rib/spar matrix. Nevertheless, the function of the panel build jigs is to insure that the relative positions of the components, e.g. stringers, skins, splice plates and reinforcings, are accurately placed. One of the most critical features to maintain is the relative stringer to stringer spacing. Accurate spacing is required to insure the fit properly with the wing rib cut outs in the final wing box assembly. Variations in this spacing can result at minimum in loss of fastener land distance or potentially in a stringer/rib pocket mismatch. Further, fastening the wing components together while the components are maintained in proper contour helps to minimize or even eliminate residual stresses when the panels are mated in the final flying configuration.

“POPPING POST” ASSEMBLY FIXTURE

The new “popping post” panel assembly fixture was conceived to address a severe floor space limitation with the Airbus UK facility. The fixtures are built upon a series of generic fabricated steel base modules, which are bolted directly to the foundation. The intermediate base modules are slotted perpendicular to the long fixture axis. These slots allow proper positioning of the generic post/receiver assemblies in the fixture Z–axis to account for the B-axis curvature of the wing panels. (See Figure 5) The X-axis spacing of these slots is approximately two feet center to center. By alternating the post assemblies in adjacent slots for different panels, two wing panels can be assembled in the same fixture.

Unique end gates located at the ends of the fixture are used to set the critical wing to body joint area. Indexes on the end gate provide the sole point of X-axis positioning for the stringers, skin and butt splices. All parts therefore grow from the end gate outboard due to temperature and fastener expansion effects.

Stringers are located outboard in Y and Z with nest plates attached to unique formboards. The formboards are connected to the posts through a pneumatically actuated linkage. The post assembly consists of fabricated steel structures approximately 5.5 meters long. The posts ride vertically on linear bearing cars mounted to the interior of the receiver box assemblies. (See Figure 8.)

When in the panel build configuration, the posts are cantilevered approximately 4 meters from the base structure. The concept of vertical cantilevered posts offers a number of inherent advantages to the overall integration of the machine and fixture. The lack of an overhead beam decreases the required throat depth of the assembly machine. The ability to drop the posts completely out of the machine path increases the overall cell efficiency by allowing the machine to work unencumbered over a wide area. The initial concerns about the stiffness and stability of the cantilevered designed were allayed through extensive testing of the entire assembly prior to manufacturing. The test set-up consisted of a representative mock-up complete with a foundation as illustrated in Figure 11.

Posts are raised and lowered with hydraulic cylinders. When the cylinder is fully retracted the post position is slightly above the final index position. This permits the post to overtravel in the vertical direction and then return down onto hard index points. This mechanism provides accurate and highly repeatable positioning. The vertical post position is the most critical component in these panel jigs since it directly effects the stringer Y-axis position.

Once the post is positioned vertically, a pneumatically actuated over center linkage moves the formboard toward into the panel. Inherent with contoured parts there is a potential for “jig lock” once the individual parts are fastened. During the manual operation, some minor jig locking issues can be overcome by exploiting the flexibility of the panels. This however would not be reliable enough in the fully automated environment. To avoid this issue the formboards draft into the stringer matrix upward at a 15-degree angle. In so doing fully automated disengagement and reengagement of the index plates with the stringers has proven quite robust. (See Figure 9)

When the formboard is in position, pneumatic stringer clamps actuate to pull the stringers into the nest indexes. The individual index positions are controlled by unique ‘index-plates’. These components are high-precision aluminum plates, which contain multiple stringer indexes (See Figure 8). Typically, between three to five stringers are indexed on any given index-plate. Each index plate is precision located during the initial fixture configuration using a laser tracker. Three to five sets of indexes are located by setting just one index-plate. This methodology provides for high-accuracy index locations, while minimizing set-up and recertification efforts. In addition, flexibility for future wing variants is maintained by allowing rapid changes to all stringer indexes.

Once all stringers and splice plates are in place the panels are then loaded into position. All panels, except panel 2, are pinned off in X on the end gate assembly and clocked into position on their trailing edge. Trailing edge supports are located along the X-axis on the bearing rails of every other post. The trailing edge index remains in position throughout the build process, which thereby provides a constant index. While panel 2 is also pinned off in X on the end gate assembly, it is clocked on its leading edge by pulling the panel up into its leading edge.

Skin clamps located on the top and bottom of the formboards are used to pull the panel into position. (See Figure 8) The skin clamps are driven with air motors and Acme screws and provide sufficient clamp force to pull the thick and highly contoured lower panels into position. During the initial panel load, compliant skin straps are attached to the skin clamps. The skin straps are used to apply the required pressure to form the skin around the fixtured stringers. Adjustable spherical feet are used to apply localized pressure coincident with the stringers position. This is especially critical to the super panel assembly where localized pressure is required to insure a smooth transition at the panel 2/3 splice interface. Once the panels are tacked the skin straps are removed and the skin clamps open and close completely under CNC control.

Each fixture is controlled by a separate GE 90/30 programmable logic controller (PLC). The PLCs for each line are linked together with one additional PLC termed the "cross over PLC". The cross over PLC acts as the intermediary between the fixtures PLCs and the machines' CNCs. Binary coded commands are passed to the fixtures to selectively activate posts and clamps. Status and error information is passed back from the fixture through the cross over PLC to the machine CNC. The E4100 CNC therefore has full control of the fixtures during automatic operation. When not under machine control the fixtures can be manually activated from each fixture control station located adjacent to the fixtures. Fixtures are automatically configured for the proper panel through a preprogrammed cycle in the each fixture PLC. This provides for completely automatic set up when changing fixture configuration.

MACHINE/FIXTURE INTERACTION

During the initial system installation, the fixture coordinate systems are carefully aligned to the machine X-axis rail coordinate system. Gravity is used to establish the Y-axis and thereby the Y/Z plane. A combination of water levels, laser trackers and conventional optical tools are used to develop and align these parallel coordinate systems. With parallel coordinate systems, the machine must then only reference one point per panel configuration to completely synchronize machine and fixture geometry. Physically this is accomplished by mounting a precision crosshair target to each of the fixture end gates. These targets are then valued using laser trackers relative to the fixture coordinate system. A matrix transformation between the fixture coordinate system and the actual wing coordinate system provides the final link between the machine, fixture and part to allow the NC programmer to develop the part programs.

When all loose components are fixtured, the machine locates to the appropriate fixture as described above and proceeds with the initial fastener tack pass. The high machine accuracy requires that the machine resynch only once per fixture to remain within tolerance through the entire 100 ft X 10 ft X 3 ft (X, Y, Z) working area. During the tack pass, the stringer side machine head works in between the vertical posts. After the assembly is tacked together, the relative position of the various components is set. All skin straps are removed. Multiple posts are then lowered, which creates a large open area in which the machine can freely operate. The system then continues under CNC control to complete the fastener installation. During this process, the post assemblies disengage and reengage under full CNC control as called out by the part program.

CONCLUSION

The new fully automated A340-600 wing panel fixtures provide a significant enhancement over previous wing panel systems. A number of important new enabling features have been introduced into these jigs to permit reliable full automatic operation. Integration of these new fixtures with the third generation E4100 assembly machines provides Airbus UK, Ltd. with a flexible advanced manufacturing cell to address long-term quality improvements and cost reductions.

ACKNOWLEDGMENTS

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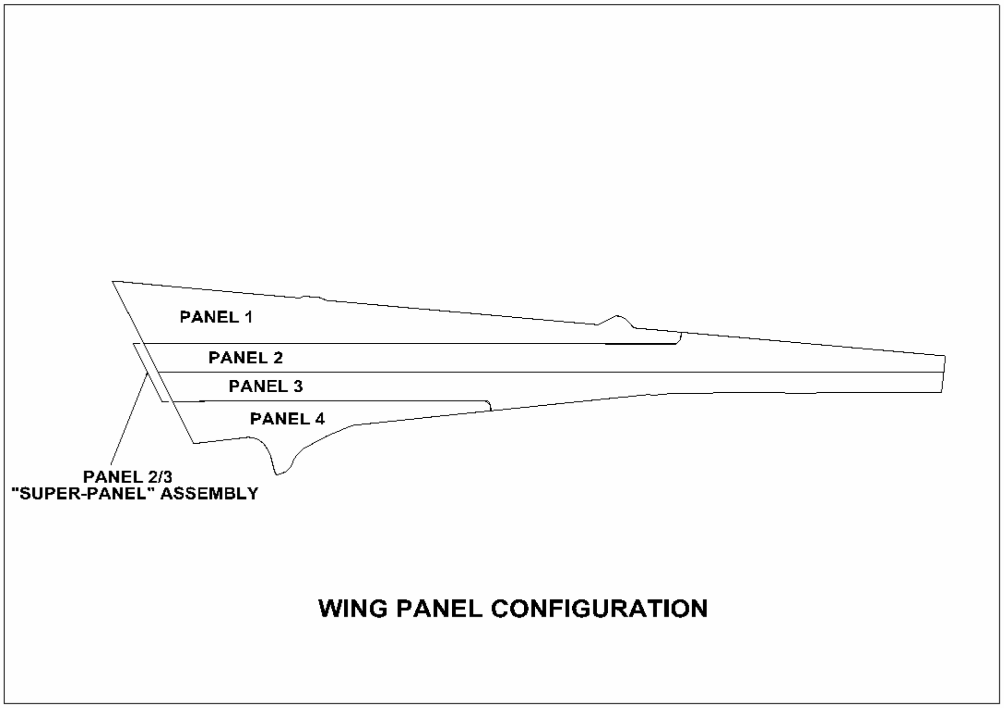


Figure 1: A340-600 Wing Panel Layout

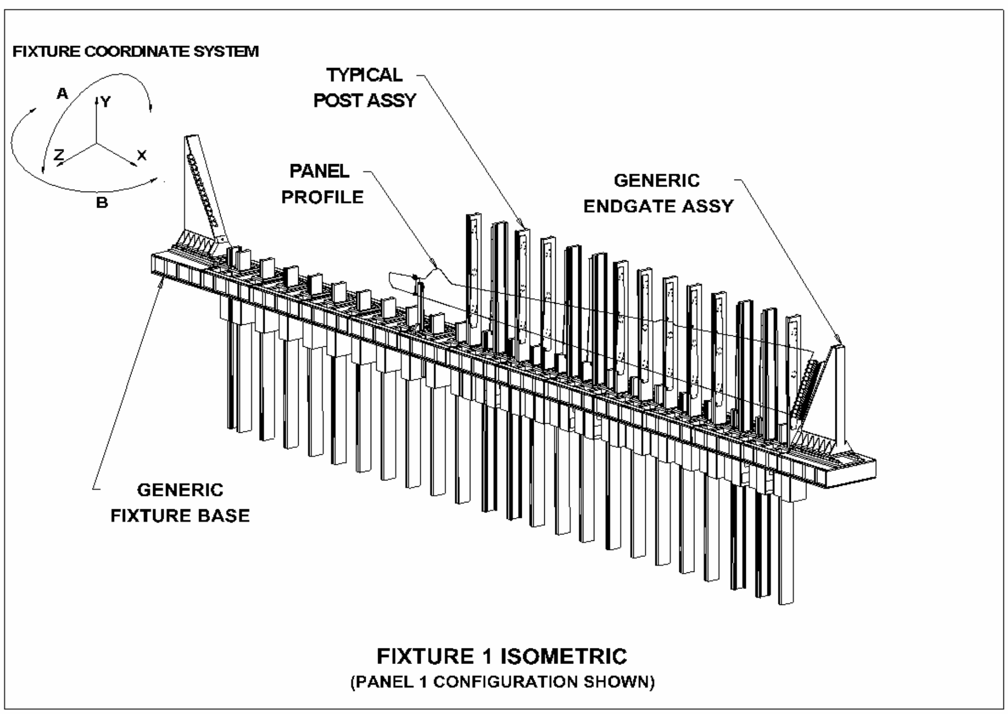
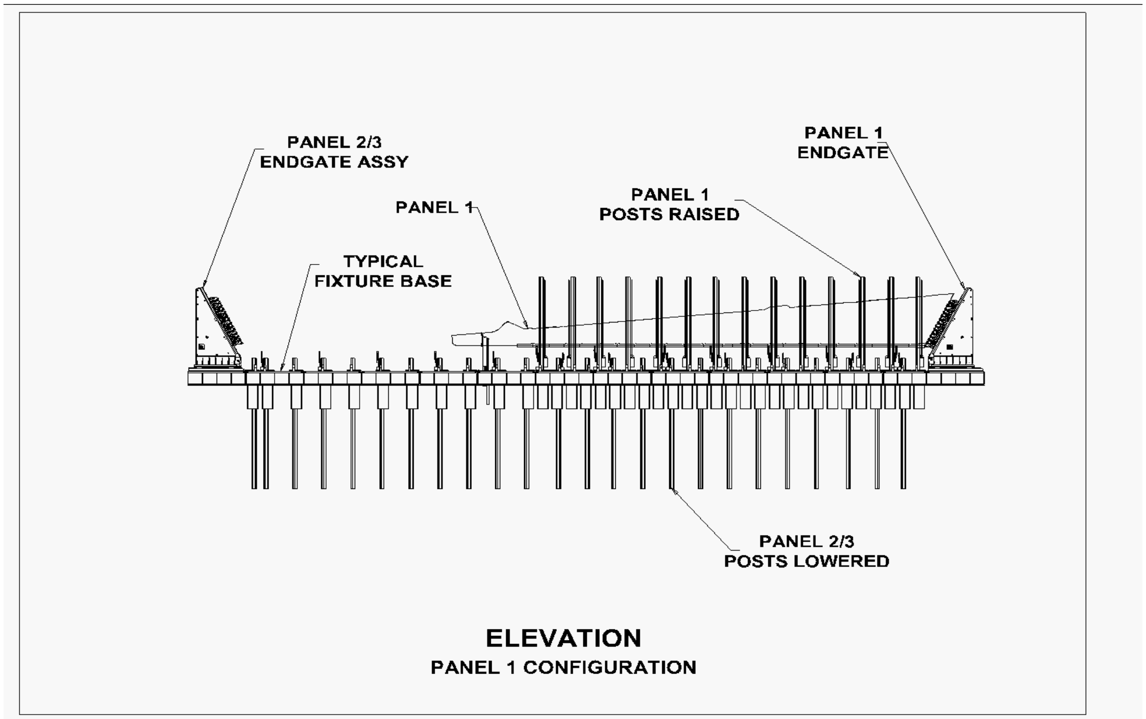


Figure 2: Flexible "Popping Post" Fixture



Fixture 3: Side View in Panel 1 Configuration

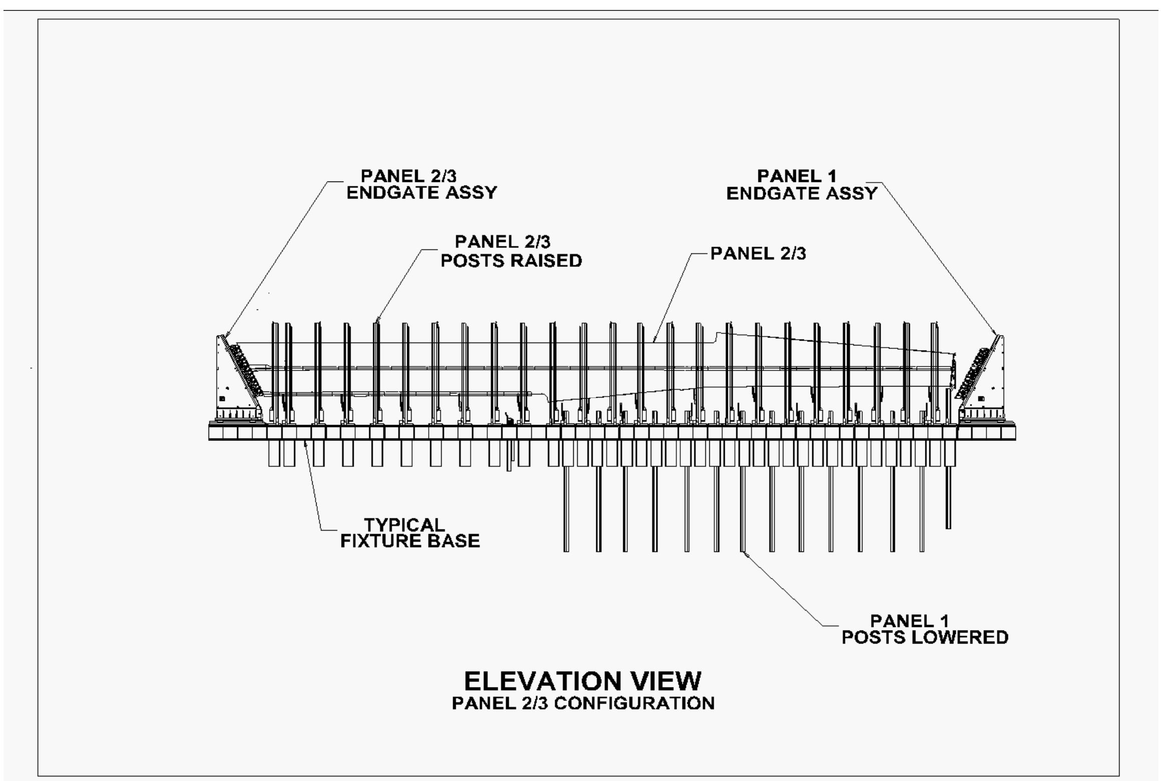


Figure 4: Side View in Panel 2/3 Configuration

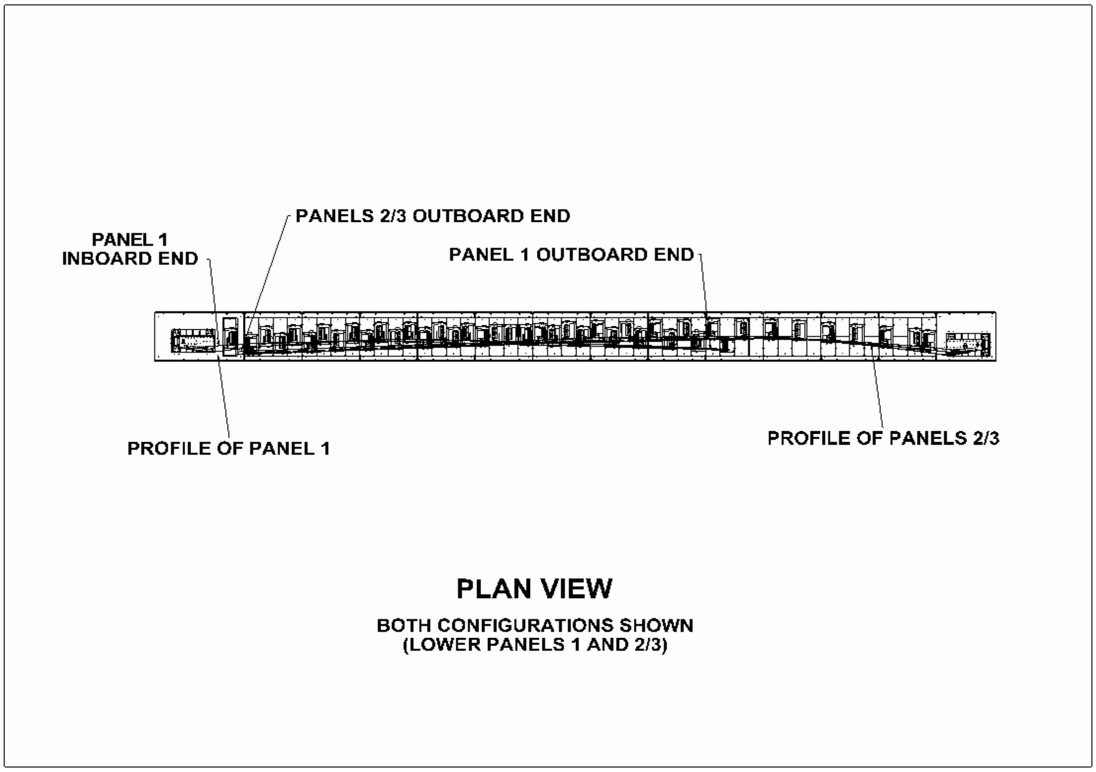


Figure 5: Plan View Illustrates Panel Curvature Accommodation

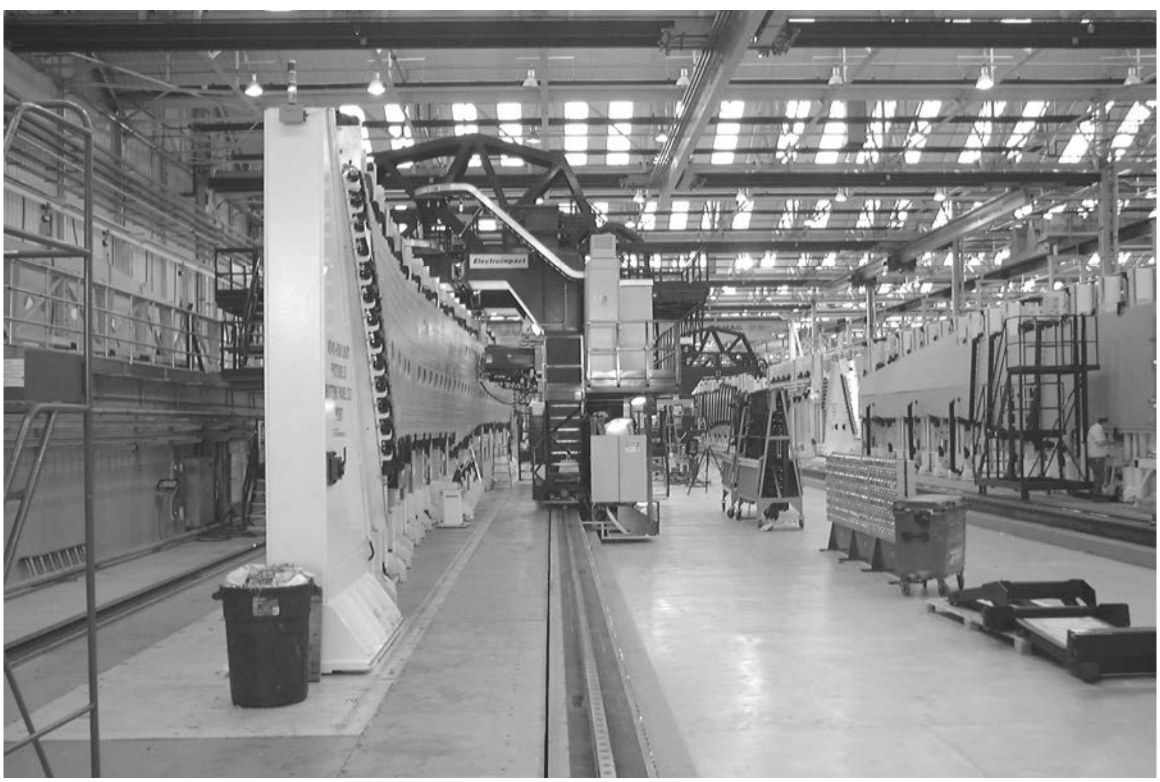


Figure 6: A340-600 Lower Panel Line: Fill Pass with E4100 Assembly machine

Figure 7: A340-600 Upper Panel Line: Tack Pass
Note: Skin strap push panel into correct contour.

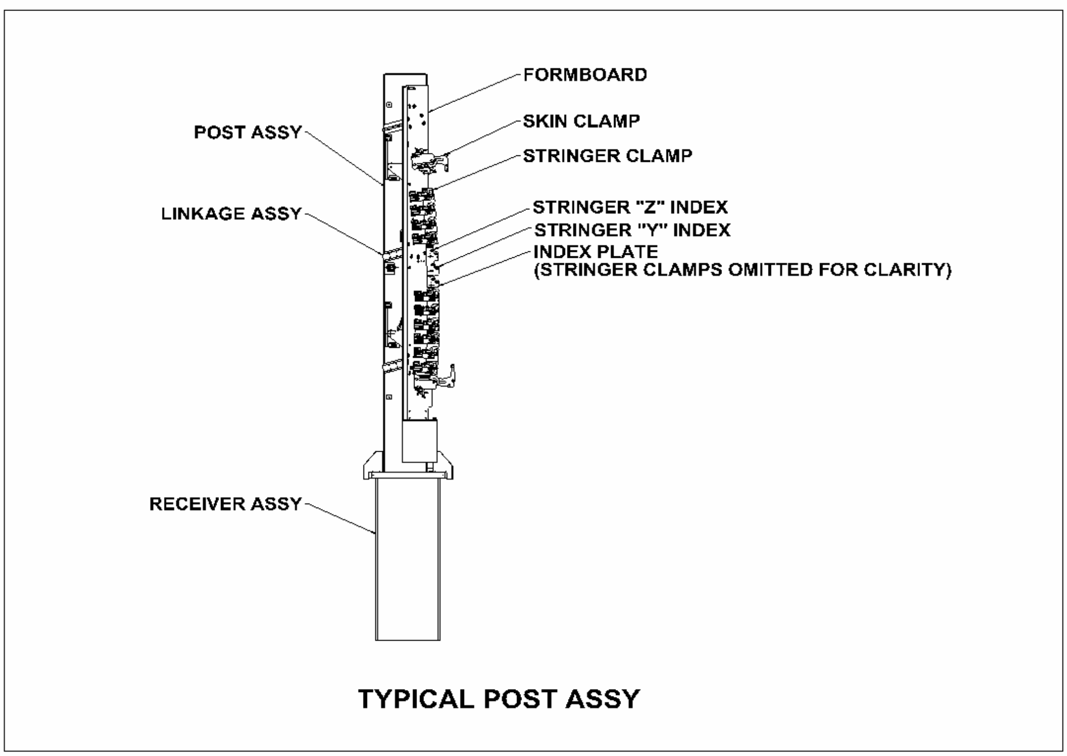


Figure 8: "Popping Post" Assembly

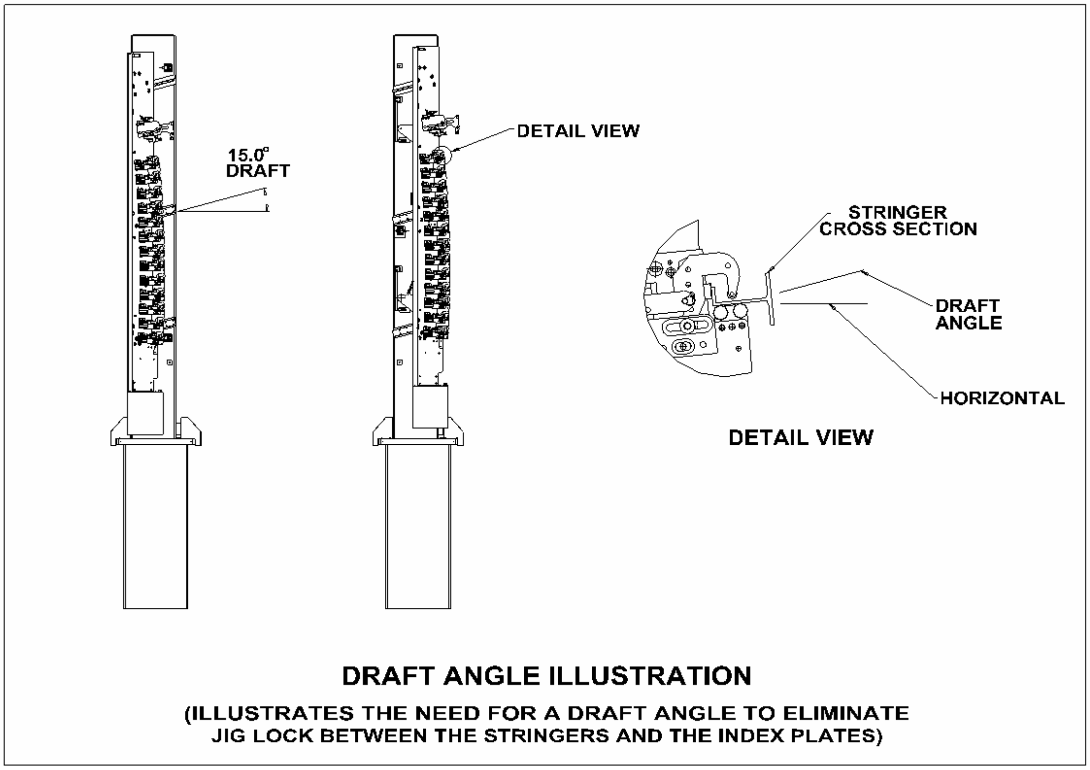
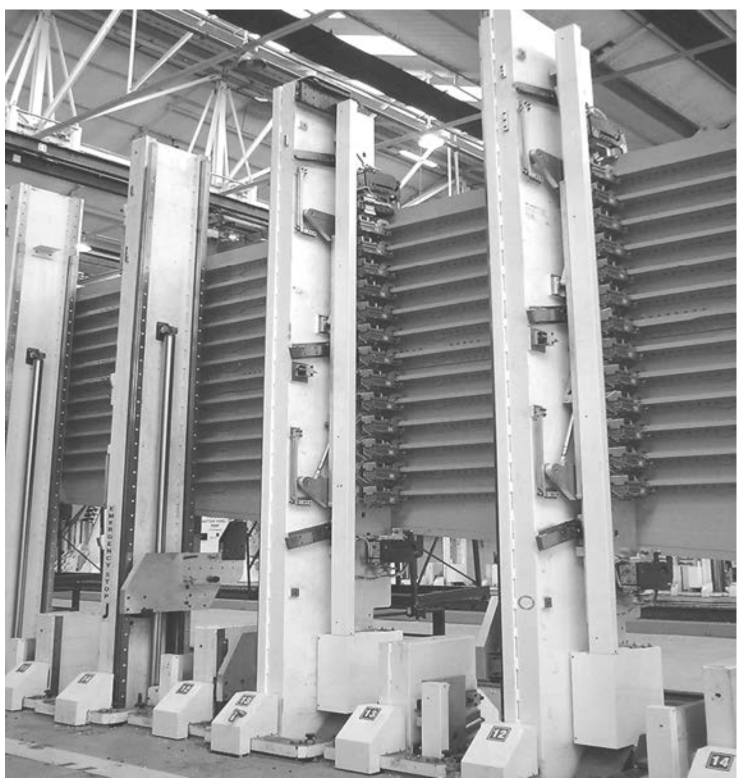


Figure 9: Formboard Travel



Fixture 10: Popping Post Assemblies: Deployed and Stored
Note: Trailing Edge Support Provides Clocking Datum

Figure 11: Technology Development Cell