Quick-Change (QC) Airplane System: A Prospective

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A new quick-change (QC) passenger/cargo aircraft system has been designed to aid in development of the short-to-medium-haul air-cargo market. Conversion times of 20 to 30 min make possible dual-purpose utilization greater than can be achieved in passenger-only airline service. Proper scheduling will allow 4 hr of cargo service per day in addition to the 7 to 8 hr spent transporting passengers. The major design objectives of simplicity, ruggedness, versatility, and compatibility with present ground and air systems were achieved by using an airline operations systems approach to the quick-change problem while maintaining careful control of detail design. Weight and performance trades were found to be acceptable when the basic passenger airplane has sufficient structural growth capability.

Cargo Markets

THE introduction of jet transports into scheduled cargo service has precipitated an unparalleled increase in air freight. Since 1962, total free world air cargo has increased by over 70% (Fig. 1). The year 1965 alone shows an air freight increase of over 25%. By 1970 it is conservatively predicted that the number of revenue ton-miles flown will be four times the 1962 figure.

Within the U. S., approximately 50% of the air-cargo business originates in six primary centers of population and industry, i.e., the so-called six major city hubs. The remaining 50% originates in secondary, regional, and local centers of population. Proposed large airplanes, combined with currently operating long-range jet freighters, will be able to meet the demand of air-cargo growth rates between major international and domestic cities, but little has been done about aircraft for the other half of the air-freight business.

Economic Aspects

To successfully develop a regional cargo market, the airline operator must provide adequate lift capacity and dependable schedules while maintaining satisfactory utilization and profitable load factors. Airline experience and economic analyses indicate that most short-to-medium-range jet transports have a work capacity exceeding that which can be utilized when the aircraft is designed strictly for cargo or passenger service alone. Aircraft scheduling, not servicing or maintenance, is the limiting factor.

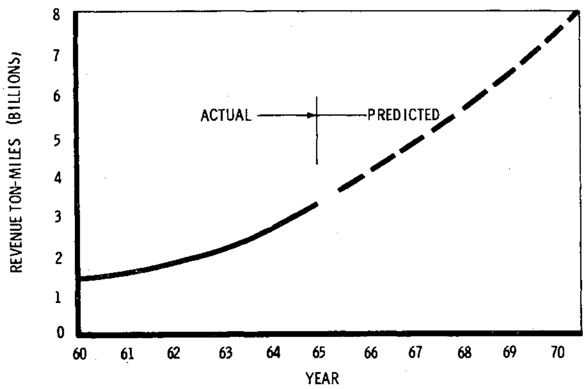

Fig. 1 Total free world air cargo.

The specialized cargo aircraft has high work capacity, but cannot operate profitably into thin markets with the required regularity. Its utilization is limited because most air freight moves during the night hours. The passenger aircraft, on the other hand, is difficult to schedule profitably during the late night hours because of the drop in passenger travel.

For a nominal cost and weight penalty, the short-to-medium-range passenger jet transport can be modified for dual-purpose service. For a slight additional penalty, the conversion from passenger to cargo or cargo to passenger use can be made quickly. Figure 2 qualitatively compares the work capacity, schedule frequency, and utilization of a specialized cargo aircraft with that of a dual-purpose airplane of the quick-change (QC) type.

Figure 3 illustrates the manner in which we expect the cargo market to develop. The growth rate for the 1965 to 1970 time period is assumed to be 20% per year. Lower-hold cargo will continue to increase with the size of passenger jet fleets. Propeller freight will, through competition from jet

Table 1 Conversion time-task relationships

	C time max(min)	Design improvement	QC time reqd max(min)
Prepare and open cargo door	40	Simplified	2
Remove closets and partition	40		
Remove seats	360	Palletized	128
Remove galleys	58		
Remove carpet and pad	174		
Fold hatrack down	80	Folded up	14
Install hatrack covers	...	Eliminated	0
Install barrier net	54	Palletized	6
Install Fume-tight curtain	16	not required	0
Install cargo transfer and restraint system	218	Semipermanently installed	9
Inspect	40	Simplified	10
Total man min required	1080		160
Elapsed time required (8-man crew)	2 hr 15 min		20 min

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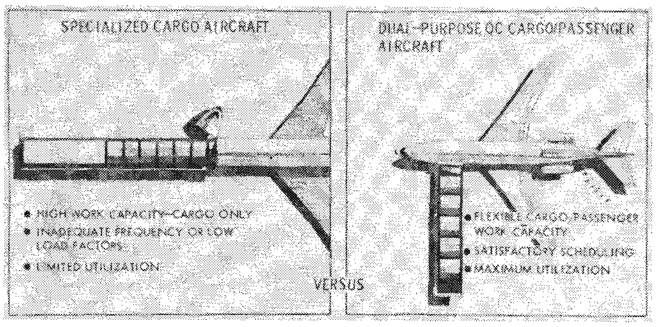


Fig. 2 Regional cargo market, aircraft economic considerations.

freight, become unprofitable except for turbine-powered aircraft. Pure jet freight between major population centers will climb to nearly 2 billion revenue ton-miles. Finally, the dual-purpose *QC* aircraft will move into the regional and local markets and by 1970 will generate cargo revenue ton-miles equivalent to the total now being flown between major cities by pure jet freighters.

QC Utilization

With the need established for a dual-purpose *QC* aircraft tailored to regional air-cargo market development, the relationship between a normal aircraft passenger day, ground time, and the time available for subsequent cargo service was examined closely. Typical airline schedules showed that approximately $13\frac{1}{2}$ clock hours are required to obtain 8 hr flight utilization in passenger service (Fig. 4). Only a portion of the remaining $10\frac{1}{2}$ nonproductive clock hours would normally be used for servicing and maintenance. The availability of additional work capacity was confirmed by utilizations of from 12 to 14 hr being achieved on longer-range jet aircraft. Assuming eight productive passenger hours, the study concluded that the *QC* system could provide a short-to-medium-range passenger/cargo jet with from 3 to 4 hr added utilization in the cargo market. Four to five clock hours would remain for conversion and maintenance.

Two examples of passenger/cargo utilization are given in Fig. 5. A daytime passenger flight from New York to Miami and back might be followed by a cargo flight from New York to Atlanta and back within the 24-hr period, still leaving sufficient time for conversion and maintenance. Or, two *QC* airplanes flying the Seattle–Denver–San Francisco route might originate opposite round-trip passenger flights in Seattle and Denver. After the passenger round trip, each airplane could be converted at its point of origin to a cargo configuration and dispatched on a one-way cargo trip to Seattle in the one case and Denver in the other. The two *QC* airplanes would then have exchanged points of origin and could be converted back to the passenger configuration for service the next day. With proper planning and ground support, the *QC* system offers maximum utilization by providing the ability to respond quickly to changes in market demand throughout the entire airline system.

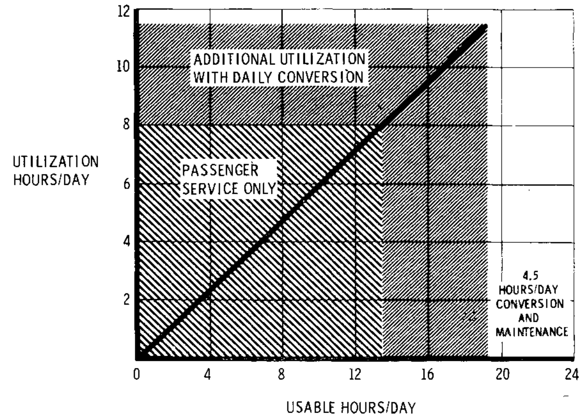


Fig. 4 *QC* utilization potential.

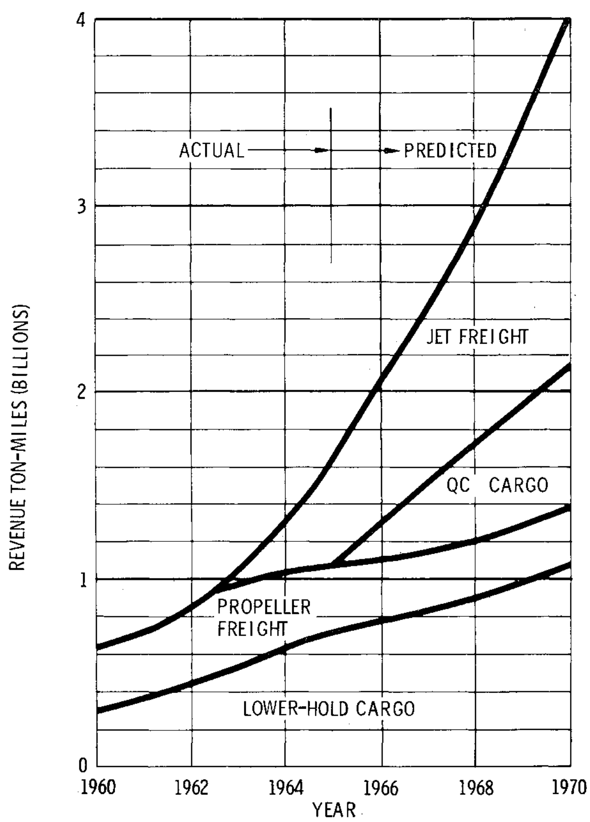


Fig. 3 U. S. domestic and international air cargo by type.

Requirements of *QC* Design

Design of the *QC* passenger/cargo system required consideration of minimum conversion times, simplicity, ruggedness, versatility of passenger and cargo loading, and compatibility with present cargo-handling systems. Key air-cargo carriers were consulted. Design hardware studies and time-motion analyses followed, aimed at solving conversion problems and minimizing conversion times.

Using time-task relationships established previously in converting a long-range jet transport, the conversion time for the short-to-medium-range airplane was found to be 2 hr and 15 min (Table 1). The various tasks were then examined critically for elimination or simplification.

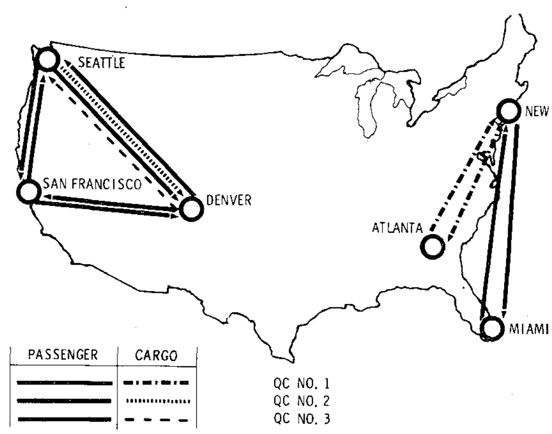


Fig. 5 Typical daily utilization.

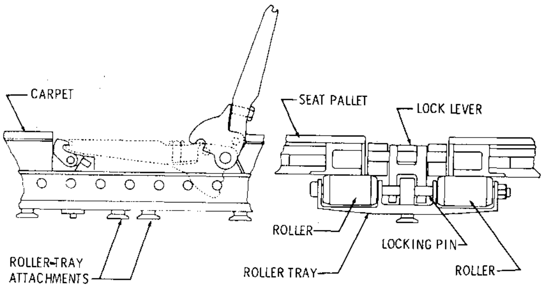


Fig. 6 ***QC*** **seat-pallet lock.**

To assure the usefulness of the *QC* concept, a one-way conversion objective of 20 to 30 min was established. It became apparent that an airplane capable of meeting this objective would have to carry its own cargo-handling system, and that for quick removal and reinstallation, the passenger interior must also utilize this system. As a result, installation and removal of the cargo-handling system, except on extraordinary occasions, were eliminated and a palletized passenger interior was introduced.

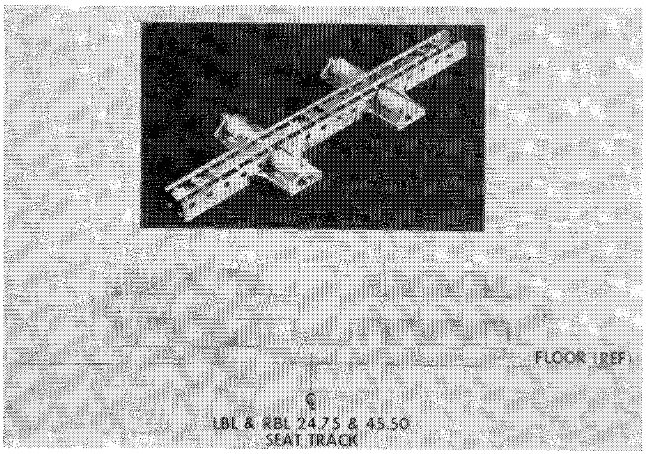


Fig. 7 ***QC*** **roller-tray cross section.**

Palletized Passenger Interior System

The *QC* passenger interior can be palletized to accommodate either mixed 4-abreast first class/6-abreast tourist seating or 6-abreast all-tourist seating. Passenger accommodations and appointments are the same as those of a standard passenger airplane.

The seat-pallet lock system was designed to assure that seat pallets may be locked at 1-in. increments throughout the cabin length. Figures 6 and 7 show how the pallet may be engaged at any position. A simple, hand-operated lock lever located just behind the rear seat leg attachment on the seat pallet is capable of engaging the roller system at 1-in. increments throughout the cabin. In addition, short seat-track inserts made integral with the seat pallet allow some variation of seat position upon the pallet itself. Figure 8 shows a typical seat pallet in position. Quick disconnects provide for electrical and water plumbing to the galleys, and the galleys were re-engineered to move inboard on their pallets to clear the hatracks and passenger service units as the galley pallet is moved forward from the airplane.

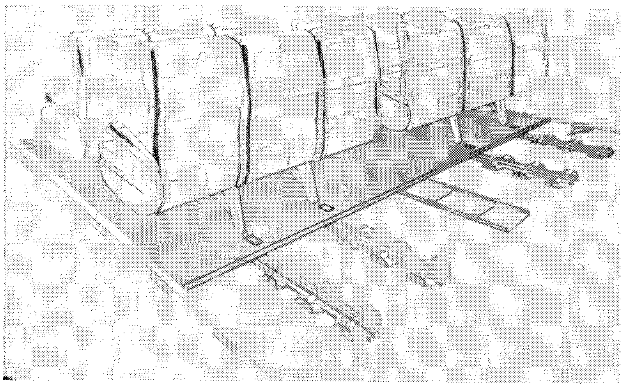


Fig. 8 ***QC*** **seat-pallet design.**

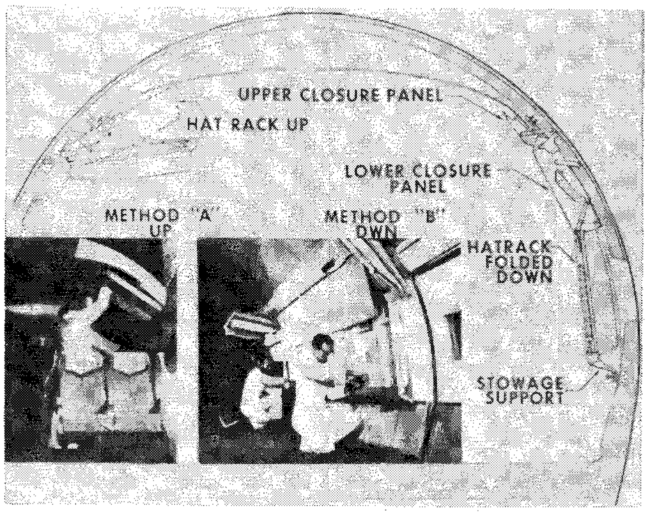
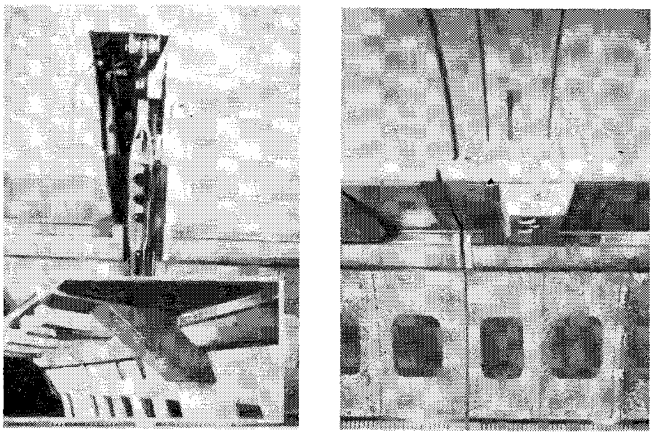


Fig. 9 ***C*** **and** ***QC*** **folding hatracks.**

Previously, hatracks were folded downward in a manner requiring the installation of protective cove panels on the interior sidewall. Figure 9 shows how the hatrack system was redesigned to fold upward without requiring additional parts. The cargo door was provided with two disappearing actuators in place of the previous single actuator, which protruded into the passenger cabin. The design eliminated any removal or reinstallation of parts (Fig. 10). Opening the cargo door became a matter of utilizing the control panel located on the interior bulkhead just inside the forward main entry door, with about 2 minutes required for operation.

The other tasks noted in Table 1 were simplified or eliminated, and analyses indicated that a 20-min conversion time could be achieved. To prove the analyses, a full-size *QC* mockup section was constructed, and conversion operations were conducted with a palletized interior and a crew of eight men. The operational mockup confirmed the time studies.

Conversion constitutes only a part of the total turnaround schedule. Figure 11 takes into account the time required to



a) Single actuator **b)** ***QC*** **actuator**

Fig. 10 ***C*** **and** ***QC*** **folding hatracks.**

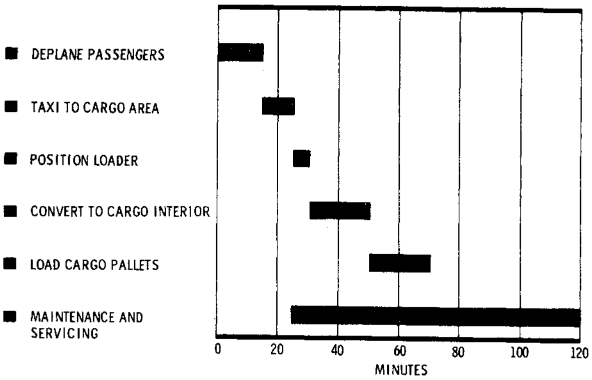


Fig. 11 Turnaround schedule, all passenger to cargo.

deplane passengers, taxi to the cargo area, position the loader, convert the passenger to a cargo interior, load cargo pallets, and service and maintain the airplane. It is seen that the turnaround time with all items considered is about 1 hr, with an additional hour available for completing maintenance if required. As noted earlier, 4 to 5 of the 24 clock hours were allotted to two-way conversions, servicing, and maintenance.

Cargo-Handling System

The *QC* cargo-handling system is pictured in Fig. 12. The entire system was engineered to a low profile height of $1\frac{1}{4}$ in. The design features continuous side guide rails to give the seat-pallet floor a continuous finished appearance, a roller tray with the intergral seat-pallet lock system, and a retractable side guide restraint located at left-hand buttock line 45.50, which permits loading of either 108-in. or 125-in. wide cargo pallets, as shown in Fig. 13.

The design of the cargo-pallet lock is simple (Fig. 14). A finger-operated lever actuates a cam and rod against spring pressure to unlock the cargo-pallet stop and allow it to fold downward into a recessed position that allows free use of the roller system. A simple hand motion raises the pallet lock into the stop position where it is held by the spring-actuated rod. Side guides, side restraints, roller systems, and structural locks were designed to withstand rough daily use. The *QC* airplane floor (Fig. 15) was reinforced significantly by the addition of a beam at the centerline running the length of the interior cabin.

System Compatibility

The *QC* system was designed to accommodate various passenger interiors that might be engineered to be interchangeable. Cargo interior compatibility is aided by designing for MATS 108-in. wide pallets, or standard 125-in.-wide cargo pallets. The cargo door is 134 in. wide, large enough to permit loading of a JT3D fan engine with accessories. The airplane *QC* system is compatible with present-day ground systems. These might be powered portable facilities, i.e., seat storage vans that provide storage space for the passenger seats and galleys and cleaning and maintenance capability within the van, or they might be fixed facilities so arranged that the airplane may park adjacent to the freight

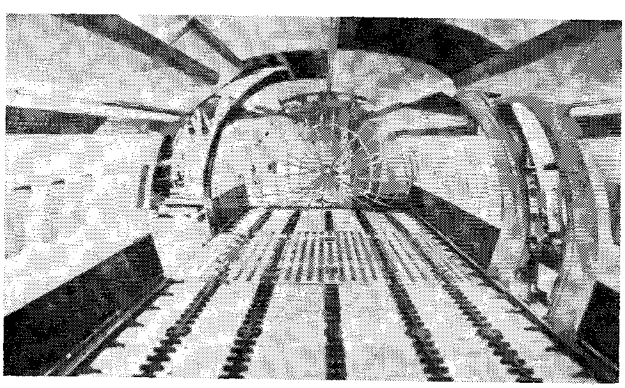


Fig. 12 *QC* cargo-handling system.

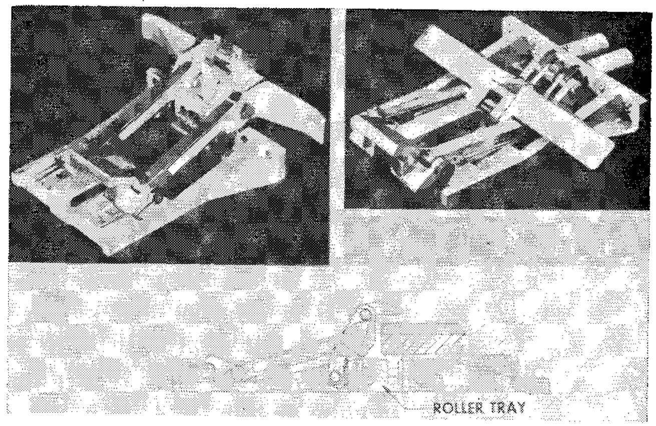


Fig. 13 *QC* retractable side restraint.

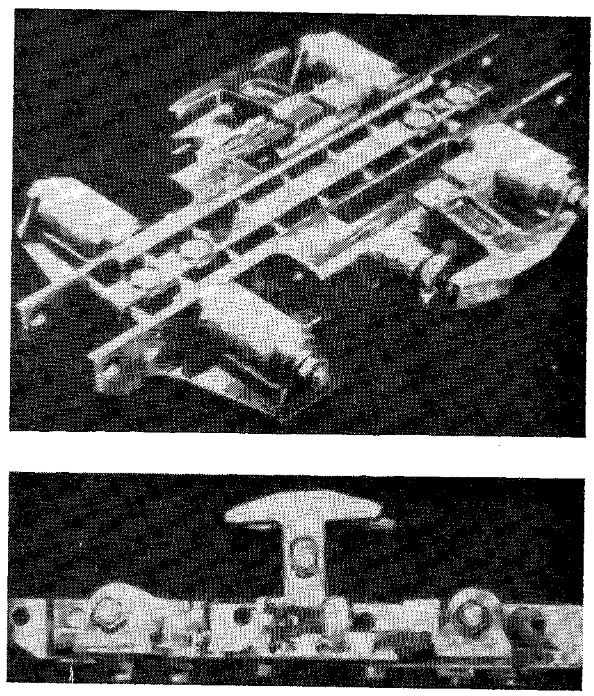


Fig. 14 *QC* cargo-pallet lock and stop.

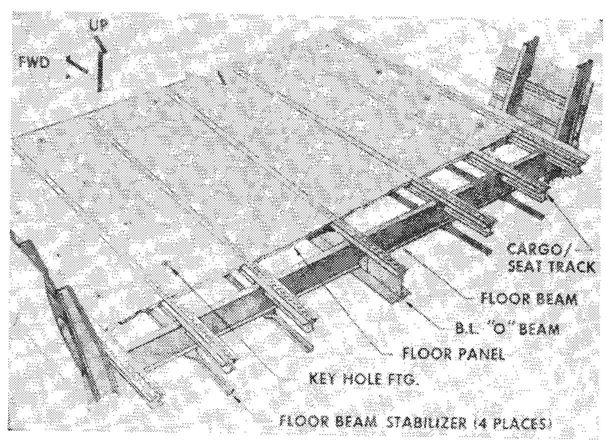


Fig. 15 *C* and *QC* floor structure.

	727 PASSENGER	727 C & QC PRIMARY CG	727 C & QC ALTERNATE I CG	727 C & QC ALTERNATE II CG (OPTIONAL)
MAXIMUM TAXI WEIGHT, POUNDS	161,000*	161,000	161,000	170,000
MAXIMUM TAKEOFF WEIGHT, POUNDS	160,000	160,000	160,000	169,000
MAXIMUM LANDING WEIGHT, POUNDS	137,500	137,500	135,000	142,500
MAXIMUM ZERO FUEL WEIGHT, POUNDS	118,000	123,500	123,500	132,000
V_{MO}, KNOTS	390	390	390	350
MAX FLAP SETTING (LANDING), DEGREES	40	40	30	30
FORWARD CG LIMITS, PERCENT				
TAKEOFF	12	12	10	11
FLIGHT	11	11	9	10
LANDING	13	13	11	13

*OPTION AVAILABLE

Fig. 16 Principal characteristics, 727*C* and *QC*.

terminal dock. In the latter arrangement, both passenger and cargo pallets would move through the cargo door and along the dock to the freight terminal for further transport or storage.

Containerization

Palletized loads must embody proper cargo restraint. To take full advantage of the *QC* system, containerization is recommended. The container may be constructed of fiberglass or some similar lightweight material with a high strength-to-weight ratio.

We have recently engaged in an extensive study to update the state of the art of upper-deck containerized systems. The objective has been to promote the design of upper-deck cargo containers that 1) provide cargo restraint integral with the container structure, 2) allow container use without dunnage, 3) are intergral with the pallet, 4) provide maximum usable volume, and 5) are compatible with current cargo systems. We are coordinating with airlines and with technical committees toward interchangeable containerization for wide-body jets throughout the industry.

Performance Trades

Static and fatigue testing methods establish the structural capability of a given airframe. The structural testing given the Model 727 airframe was the most extensive ever performed on a transport aircraft prior to its entering commercial service. This testing and design p'anning has made possible the convertible passenger/cargo model. Principal characteristics of the 727QC are shown in Fig. 16. Note that all structural weight limits have been increased over those of the parent 727. The *QC* airplane is capable of operating within the same limitations as the standard passenger 727, which enables them to be scheduled in the same manner. An alternate set

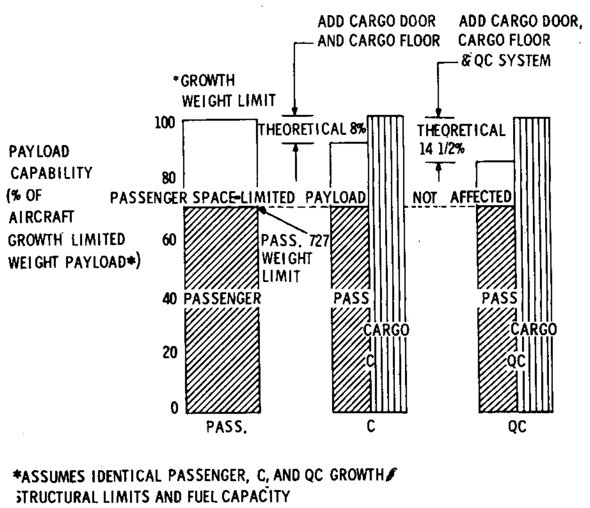
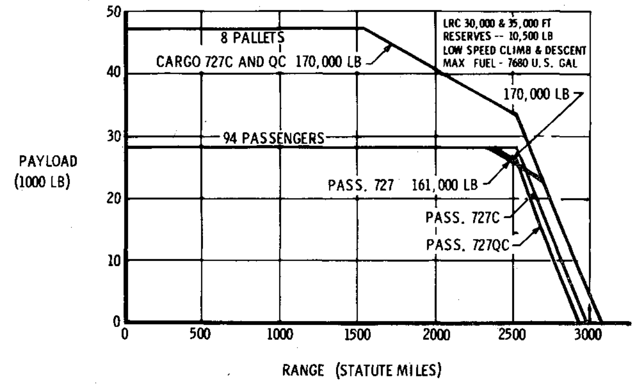


Fig. 17 Weight payload trades for convertibility.



AIRCRAFT	PASSENGERS	BAGGAGE (LB)	CARGO (LB)	OEW (LB)
727C & QC	0	0	46,500	85,500
727	94	3760	9070	85,750
727C	94	3760	9070	89,750
727QC	94	3760	9070	92,750

Fig. 18 Payload-range comparison.

of operating limits provides extended forward c.g. limits of 9, 10, and 11% with a 135,000-lb landing weight, maximum operating flight speed of 350 knots, and flap setting of 30°. Utilization of the highest set of structural limits, which permits over 4 tons additional payload, will normally be confined to the cargo operation.

Adding the cargo door, strengthening the cargo floor, and making other changes in the parent 727 increased the 727*C* operating empty weight approximately $4\frac{1}{2}$%. Quick-change features added another $3\frac{1}{2}$%, for a total of 8%. These weight increases would have come directly out of payload; however, as shown in Fig. 16, the 727*C* and *QC* structural weight limits were extended to more than offset the added empty weight. As a result, the passenger space-limited payload was not affected (Fig. 17).

When the cabin interior is lengthened to permit passenger loading of the growth weight limit, as in the derivative long-body 727-200, the theoretical *C* and *QC* passenger payload losses shown in Fig. 17 become very real. However, because of further changes in structure, they may not be identical to the losses shown.

Figure 18 presents the passenger payload-range picture. Again, because of the increased structural capability of the 727*C* and *QC* airplanes, no payload or range penalty is experienced. In fact, the payload range of the 94-passenger airplane is increased about 10% for the 727*C* and 2% for the 727*QC*. The maximum cargo payload range is shown in Fig. 18. Over 23 tons of cargo can be carried in the all-cargo configuration to distances of about 1500 statute miles.

The 727 high-lift system provides the passenger/cargo convertible airplanes with comparable takeoff characteristics. Takeoff field lengths for a particular passenger mission are compared in Fig. 19. The *C* and *QC* dual-purpose aircraft require 470 and 700 ft, respectively, additional FAR takeoff

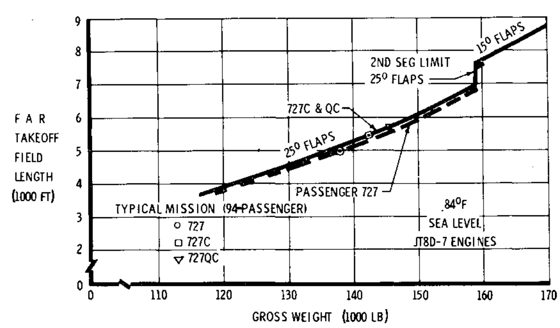


Fig. 19 Takeoff field length comparison.

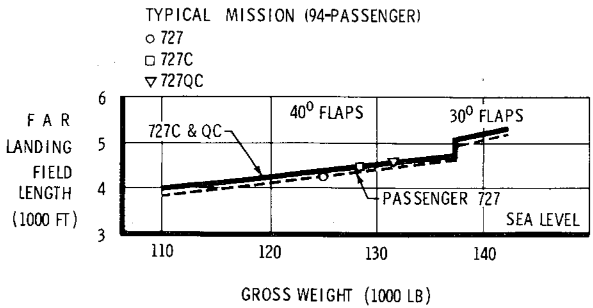


Fig. 20 Landing field length comparison.

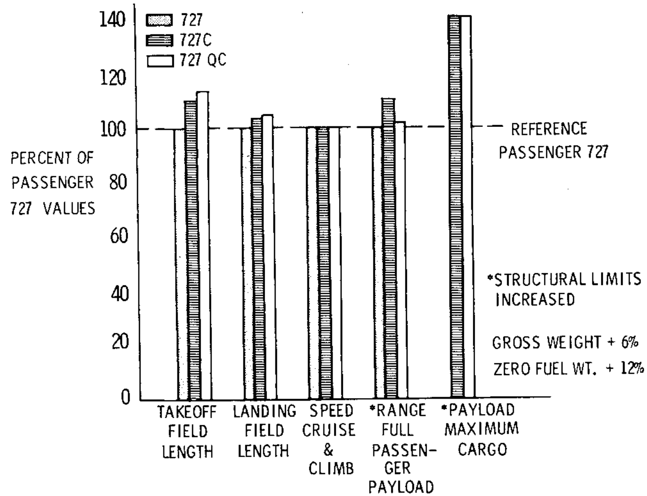


Fig. 21 Performance trades for convertibility.

field lengths for the example chosen. Landing field lengths for the same mission are compared in Fig. 20. A very small penalty is experienced.

The C and QC performance trades for the short-to-medium-range jet transport are summarized in Fig. 21. The maximum structural payload has been increased 40% over that of the parent 727. Takeoff field length for a typical passenger mission increases up to 14%. Landing field length for the same mission experiences only a 3 to 5% increase. Cruise speed remains essentially the same, but the V_{mo} for climb must be reduced from 390 to 350 knots (about 10%) at high gross weights and/or forward c.g. limits to accommodate structure. However, for most passenger applications, a climb speed of 390 knots may be used. Finally, 727C and QC ranges at full 94-passenger payload with baggage and freight actually increase somewhat over that of the passenger 727 because of the increased 727C and QC structural weight limits.

Conclusions

A dual-purpose passenger/cargo jet can meet the need for air-cargo transportation in the lower half of the cargo market. The added utilization made possible by the QC aircraft allows scheduled service to developing markets that are difficult to serve profitably with straight cargo aircraft. Attainment of design objectives—minimum conversion time, simplicity, ruggedness, versatility, and compatibility with present ground and air systems—was the result of a systems approach to the quick-change problem while maintaining careful control of detail design. With regard to weight and performance trades, the QC system can be successfully tailored to a passenger jet transport if the basic airplane has sufficient growth capability.

The lower cargo holds of passenger jets are carrying air cargo to many communities and are creating a demand for the added freight capacity of the QC airplane. In like manner, QC aircraft, through market development, can be expected to increase the demand for the specialized freighter. The QC aircraft can be assigned to a specialized passenger or cargo task. More likely, it will continue its dual function, i.e., to penetrate and develop additional passenger and cargo markets.