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TERMINAL-AREA FLIGHT PROCEDURES AND ROUTE DESIGN FOR SUPERSONIC TRANSPORT NEW YORK-TRANSATLANTIC OPERATIONS

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16. Abstract

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SUMMARY

The results of an analytical investigation of two departure and arrival transition procedures between John F. Kennedy International Airport and projected North Atlantic track systems for supersonic transport (SST) operations are presented. The procedures studied were: (1) separated departure and arrival transition routes with departures made at supersonic speeds, and (2) superimposed departure and arrival transition routes with departures restricted to subsonic speed until the airplane is on the track system. For both procedures, transition routes with intercept angles of 30° to 90° to both six- and four-track systems were investigated. Track spacings of 30 and 60 nautical miles were studied.

The principal results are presented in terms of the penalties in fuel, time, and distance (based on a great circle mission) for operation on the several transition routes and track systems studied for each of the two transition procedures. Transitions at the shallowest intercept angles provided the smallest average (system) penalties in fuel and distance for both types of transition procedures. On a systems basis, separated departure and arrival transition procedures provided smaller time penalties than superimposed departure and arrival procedures. Variations between four- and six-track systems and 30- and 60-nautical-mile track spacings had, in general, only small effects on fuel and time penalties.

For the separated departure and arrival transition route procedure, the least penalties on the average were found when arrivals were handled on the inner set of tracks and departures on the outer set of tracks. For the superimposed departure and arrival transition route procedure, the converse was true. For the preferred methods of departure and arrival track allotment in each case, the average penalties with the separated transition route procedures were only slightly different than those with the superimposed procedure. Choice of the transition procedure in the New York area would thus appear to depend on consideration of airspace availability and on preferred departure and arrival track allotments at the European end of the track system.

INTRODUCTION

Separation of supersonic transport (SST) traffic over the North Atlantic will be accomplished by use of a parallel-track system. Lateral, rather than vertical, separation of cruising SST traffic is required because of the high increase in fuel consumption which occurs during off-optimum altitude operation of the SST. This track system may be considered as basically an airways system for supersonic speed high-altitude operations above about 12.19 km (40 000 ft). Because of the supersonic speeds, the track system must be situated so that no track is closer than about 25 nautical miles from the shoreline in order to avoid propagation of the sonic boom on land. An example of such a system having six tracks spaced at 30-nautical-mile intervals is shown in figure 1. For such a track arrangement, departure transition routes from New York's John F. Kennedy (JFK) International Airport will be a minimum of about 75 nautical miles in length (distance to inner track). The SST, however, can reach supersonic speeds 50 to 60 nautical miles from take-off before the turn from the transition route to the track system. With this arrangement, the turns would be made at various speeds covering the supersonic speed range, depending on the intercept angle and track used.

Results obtained in previous simulation studies of the SST operating in air traffic control (ATC) systems (refs. 1 and 2) have shown that, because of the increase in drag, turns at supersonic speeds such as turns from departure transition routes to track systems were detrimental to SST performance in reducing the climb/accelerate capability and in significantly increasing fuel requirements. On the other hand, the alternative of a subsonic speed cruise operation until the turn on to the track system has been completed increases flight time and also may result in increased fuel requirements. For first-generation supersonic transports, an increase in fuel requirements is critical because of the large effects on payload. This increase results from the small ratio of payload to airplane weight (approximately 6 to 7 percent) and high ratio of mission fuel (total fuel less reserves) to airplane weight (approximately 45 percent). An increase in fuel requirements of 1 percent of mission fuel is consequently equivalent to about a 7-percent reduction in payload.

The present investigation was made to study both supersonic and subsonic speed departure transitions to establish preferred procedures both from economic and airspace considerations. In order to examine the problem on a systems basis, the investigation included study of arrival transition procedures compatible with the departure procedures. For supersonic departure transitions, a system with separate departure and arrival transition routes designed to effect lateral separation of the climbing and descending traffic was used. For subsonic departure transitions, a system with basically common departure and arrival transition routes (superimposed departure and arrival transition routes) was used. In this system, separation was effected by the arrivals overflying the departures. The latter arrangement required less airspace than the separate transition route structure. Examples of the two transition route systems are shown in figures 2 and 3 for two departure and arrival track flow configurations. For each transition structure, several intercept angles of the transition route with the track system were analyzed. Four- and six-track arrangements and 30- and 60-nautical-mile track spacings for two departure and arrival flow configurations were used.

The results presented include fuel, time, and distance penalties for operations on the various transition routings and track arrangements examined for both departures and arrivals. On a systems basis, comparisons of these penalties are made for separated and superimposed transition route structures, departure and arrival flow configurations, and track spacings.

SYMBOLS

Measurements and calculations were made in U.S. Customary Units. They are presented herein in the International System of Units (SI) with the equivalent values given parenthetically in the U.S. Customary Units.

C_D	drag coefficient, D/qS
$C_{D,min}$	minimum drag coefficient
C_L	lift coefficient, L/qS
$C_{L,min}$	lift coefficient for minimum drag coefficient
$C_{L,o}$	lift coefficient at $\alpha = 0^o$
C_{L_α}	lift-curve slope, $\partial C_L/\partial\alpha$
D	drag, newtons (pounds)
g	gravity constant, 9.81 m/sec^2 (32.2 ft/sec^2)
h	altitude, meters (feet)
K	induced-drag constant
L	lift, newtons (pounds)

M	Mach number
m	mass, kilograms (slugs)
m_o	initial mass, kilograms (slugs)
p	rolling velocity, radians/second
q	dynamic pressure, N/m^2 (lb/ft^2)
S	wing area, $meters^2$ ($feet^2$)
T	thrust, newtons (pounds)
t	time, seconds
V	true velocity, m/sec (ft/sec)
V_x	velocity in x-direction, m/sec (ft/sec)
V_y	velocity in y-direction, m/sec (ft/sec)
$\dot{w}$	fuel flow, kg/sec (lb/sec)
x	distance in an easterly direction, meters (feet)
y	distance in a northerly direction, meters (feet)
α	angle of attack, degrees
γ	flight-path angle, degrees or radians
δ_{th}	throttle deflection, percent
ϕ	bank angle, degrees or radians
ψ	heading angle, degrees or radians

Dots over symbols denote differentiation with respect to time.

ANALYSIS

The analysis was made for a four-degree-of-freedom point-mass model of a supersonic transport design. The calculations were performed on a digital computer.

Kinematic Equations

The kinematic equations for the four-degree-of-freedom point mass system are given as follows:

$$\dot{V} = \frac{T \cos \alpha - D}{m} - g \sin \gamma$$

$$\dot{\gamma} = \frac{(T \sin \alpha + L)\cos \phi}{mV} - \frac{g}{V} \cos \gamma$$

$$\dot{\psi} = -\frac{(T \sin \alpha + L)\sin \phi}{mV \cos \alpha}$$

where

$$T = f\left(M,h,\delta_{th}\right)$$

$$D = C_D q S$$

$$C_D = C_{D,min} + K\left(C_L - C_{L,min}\right)^2$$

$$C_{D,min}, C_{L,o}, K = f(M)$$

$$L = C_L q S$$

$$C_L = C_{L,o} + C_{L_\alpha}\alpha$$

$$C_{L,o}, C_{L_\alpha} = f(M)$$

$$m = m_o - \dot{m}\ dt$$

$$\dot{m} = \dot{w}$$

$$\dot{w} = f\left(M, h, \delta_{th}\right)$$

$$V_y = V \cos \gamma \sin \psi$$

$$V_x = V \cos \gamma \cos \psi$$

$$V = \sqrt{V_x^2 + V_y^2}$$

$$\dot{h} = V \sin \gamma$$

$$\phi = \int p \, dt$$

$$x = \int V_x \, dt$$

$$y = \int V_y \, dt$$

SST Characteristics

The SST configuration used in the study had the lift and drag characteristics of a double-delta gull wing and was designed to have a cruise Mach number of 2.7. Thrust and fuel characteristics were representative of four afterburning turbojet engines. The aerodynamic characteristics, programed as a function of Mach number, were based on a combination of wind-tunnel test data and theoretical analyses. The installed performance characteristics of the engines, based on engine manufacturer's guaranteed specifications, were programed as functions of Mach number, altitude, and throttle deflection. At take-off, the airplane had a mass of 340 000 kg (750 000 lb), a thrust-mass ratio of 0.48 for maximum augmented power condition, and a wing loading of 4670 N/m^2 (97.5 lb/ft^2).

SST Operating Procedures

The climb and descent schedules along which the SST was operated are given in figure 4. The basic climb schedule corresponded to operation at the maximum operating limit speed. The climb schedule shown by the solid line was used for the separated departure and arrival transition routes, so that the turns from the transition routes to the track systems were made at supersonic speeds. For the superimposed departures, however, the climb schedule was interrupted by a constant Mach number climb at $M = 0.90$ to the altitude for best subsonic cruise 8.5 to 9.1 km (28 000 to 30 000 ft), as shown by the dashed line. Subsonic cruise was then performed until the turn on to the track system was completed. The SST was then accelerated at constant altitude to the basic climb schedule and the climb resumed to the initial cruise altitude of 18.29 km (60 000 ft).

The descent schedule given in figure 4 was used for all descents. Descent initiation from the final cruise altitude of 20.12 km (66 000 ft) was calculated so that an altitude of 12.19 km (40 000 ft), corresponding to a Mach number of about 0.96, was reached at the intersection of the transition route and the inner track (at least 25 nautical miles offshore) to prevent impingement of the sonic boom on land. The descent was checked upon reaching 4.60 km (15 000 ft), and subsonic cruise at a Mach number of 0.6 was performed to the holding point. The climb and descent schedules were not interrupted by any simulated air traffic control constraints to the vertical flight path.

For the superimposed transition route operations, altitude separation of the departing and arriving traffic was inherently effected because of the restriction in altitude to 12.19 km (40 000 ft) at the inner track for arrivals, and the subsonic cruise at 9.1 km (30 000 ft) or less until the turn on to the track system was completed in the departures.

For the basic climb schedule, maximum unaugmented thrust was used up to $M = 0.90$. At $M = 0.90$, the thrust was increased to the maximum augmented (full afterburner) level. Upon nearing cruise conditions, the thrust was reduced to a partial augmented-thrust level corresponding to the required thrust for constant (Mach number cruise-climb) flight. In the descents, the thrust was initially reduced only to 71 percent of the maximum engine speed to insure sufficient cabin pressurization. At a Mach number of 1.8, the thrust was reduced to the flight-idle condition. Thrust was increased to that required for level flight at a Mach number of 0.6 upon reaching an altitude of 4.60 km (15 000 ft). All turns were made at a bank angle of 25°.

Calculation Method

The calculations of fuel, time, and distance for track system operations are referenced to those for a mission consisting of a direct (great-circle) operation of 3660 nautical miles. (See fig. 5(a).) Mission fuel and time are defined as those for operations along a great-circle route from start of take-off to touchdown. Trip fuel, time, and distance are defined as those for operations along a transition route to or from the track system and a selected track. (See figs. 5(b) and 5(c).) The calculations do not include fuel for taxiing in and for en route reserves or the times for holding, for taxiing in, or for proceeding to an alternate airport.

For departures, the calculation of trip fuel, time, and distance was initiated at an altitude of 0.46 km (1500 ft) at 5 nautical miles from start of take-off. For the initial condition, the weight was reduced by 4.7 percent of mission fuel for taxi, take-off, and climb to 0.46 km (1500 ft) operations. The elapsed trip time was taken as the total of 10 minutes for taxi, 43 seconds for take-off, and 1.0 minute for climb to 0.46 km (1500 ft). The calculations for each departure were continued through climbout and in cruise along the selected track to a point 400 to 700 nautical miles toward destination, depending on the track and transition route intercept angle. The fuel used during the remainder of the cruise was obtained from a calculation of the final cruise weight by use of the Breguet range equation. The airplane was assumed to be operated in constant Mach number cruise-climb flight at the altitudes to optimize the flight efficiency factor (ratio of the product of Mach number and lift-drag ratio to the specific fuel consumption). Descent fuel was taken as 1.8 percent of mission fuel and descent time as 26 minutes corresponding to a descent range of 250 nautical miles.

For the arrivals, the calculations of trip fuel, time, and distance were initiated at a point on the selected track at a distance of from 300 to 450 nautical miles before the John F. Kennedy International Airport, depending on the track and transition route intercept angle. For the initial arrival conditions, the weight was reduced by the fuel for taxi, take-off, climb, and cruise-climb operations to the selected distance before destination. The elapsed trip time was taken as the total of 10 minutes for taxi, 43 seconds for take-off, 24.4 minutes for climb, and the time required to cruise from initial cruise (340 n. mi. from the departure airport) to the selected distance before destination. The calculations were continued throughout the descent to arrival at the holding point at an altitude of 4.57 km (15 000 ft). For the remainder of the descent to touchdown, the fuel was taken as 0.9 percent of mission fuel and the time as 7.8 minutes.

RESULTS AND DISCUSSION

The basic results are presented in figures 6 and 7 in terms of departure and arrival trip values of fuel, time, and distance relative to mission values of these quantities in order to define the penalties of operating on the transition route and track system. Trip fuel in percent of mission fuel, and trip time and distance increases over mission values are shown for both the separated and superimposed transition procedures. Results are given for operations to and from each of seven tracks spaced at 30-nautical-mile intervals for transition route intercept angles of 30°, 45°, 60°, 75°, and 90°. The results were obtained for seven tracks spaced at 30-nautical-mile intervals in order to allow study of four-track systems with 60-nautical-mile track spacing as well as four- and six-track systems with 30-nautical-mile track spacing.

In order to put the fuel penalties for operation on the transition route and track system in proper perspective, the reader is reminded that an increase in fuel requirements of 1 percent of mission fuel is equivalent to a reduction in payload of about 7 percent. (See "Introduction.")

Departures

For departures, the results show that the fuel penalties for operation in the system (fig. 6(a)) vary from about 1 to 5 percent of mission fuel depending on the transition procedure, the intercept angle, and the track followed. For both types of transition procedure, the least penalty is incurred at the shallowest intercept angle, 30°. The fuel penalties are little different for the two transition procedures for the inner tracks, but the penalties are greater for the superimposed transition route procedure for the more distant tracks; this result shows the impact on fuel penalties of the subsonic cruise operation until the airplane is on the track system used in this procedure.

The trip time increase in departures (fig. 6(b)) indicates penalties of from 1 to 36 minutes. The separated transition route procedure results show the least penalties (all less than 10 minutes), the shallowest (30°) intercept angle providing the smallest penalties. For the superimposed transition route procedure, the least penalties occur at the 60° and 75° intercept angles. The penalties are higher at the lower intercept angles because of the longer subsonic cruise stages in those operations. The slightly higher increase in trip time for the 90° over the 60° and 75° intercept angle transitions results from an increased trip distance in this case.

The trip distance increase in departures (fig. 6(c)) shows penalties of from about 20 to 250 nautical miles. The penalties are somewhat less for the separated transition route procedure especially at the higher intercept angles and in operations to the outer tracks because of the longer turn radii at supersonic speeds.

Arrivals

For arrivals, the results show that the fuel penalties (fig. 7(a)) also vary from less than 1 percent to about 5 percent of mission fuel. The least penalty occurs for the shallowest intercept angles; the fuel penalties are little different for the two transition procedures for the inner tracks; and the penalties are greater for the superimposed transition route procedure for the more distant tracks. For separated transitions at 45°, arrivals via Coyle (CYN) used 1.5 percent more mission fuel than arrivals via Riverhead (RVH) because of the greater trip distance.

The trip time increase in arrivals (fig. 7(b)) indicates penalties of from 2 to 13 minutes. The differences in trip time increase between the two transition route methods are small. For both transition route procedures, the least penalties occur at the higher intercept angles because of the shorter subsonic descent phase after crossing the inner track. For separated transitions at 45°, the added trip distances involved in the arrivals via CYN compared with arrivals via RVH result in an increase of about 2 minutes in trip time.

The trip distance increase in arrivals (fig. 7(c)) shows penalties of from 25 to 275 nautical miles. The penalties are least for the shallowest intercept angle and for the separated transition route procedure.

New York Area Systems Analysis

The results given in figures 6 and 7 were used to determine the total system fuel, time, and distance penalties for the several track system and transition route configurations illustrated in figures 8 and 9.

For both types of transition routes, six- and four-track systems were studied. The six-track systems had track spacings of 30 nautical miles, the minimum spacing considered possible with inertial navigation equipment. Four-track systems with 30- and 60-nautical-mile track spacing were used. Traffic flow arrangements of inner-track departures, outer-track arrivals, and vice versa, were considered. Each figure shows all the transition routes studied for that configuration; in actual air traffic control system operations, only one set of departure and arrival transition routes (usually having the same intercept angle) would normally be employed. For all transition routings, the departures were made directly from the John F. Kennedy International Airport to the departure track. The arrivals in the separated transition routings were made directly from the track to either the RVH or CYN holding points. Arrivals on the superimposed transition routes were common with the departure route from the track to the inner track at which point the route diverged to the nearest of the holding points.

Traffic was assumed to be operating equally on all six or four tracks, depending on the configuration. For the separated transition route procedure (fig. 8), the departure and arrival traffic was considered to operate on single noninterfering routes such as (fig. 8(a)) a combination of a 30° intercept angle departure transition route to tracks 1, 2, and 3 and a 45° intercept angle arrival transition route from tracks 4, 5, and 6. As illustrated, the combination of a 45° departure transition and a 45° arrival transition was also considered. The combinations of departure and arrival transition routes were chosen to provide separation of traffic equal to or greater than the track spacing. For the superimposed transition route procedure (fig. 9), the traffic was considered to operate only on one transition route. The results of these system analyses are given in figures 10 to 13. The values of trip fuel, trip time increase, and trip distance increase for each departure and arrival operation are shown together with the averages which are considered to be the overall measurements of system effectiveness.

As would be expected from the results presented in figures 6 and 7, system operations using the shallowest intercept angles provide the least penalties in fuel and distance for both types of transition procedure. (See figs. 10 to 13.) With regard to time, system operations with the separated transition route procedure provide smaller penalties than operations with the superimposed transition procedure and these penalties are relatively independent of intercept angle. Comparison of the effect of number of tracks (configurations A with C and B with E) shows only slightly smaller penalties in fuel and time on the average for a four-track system compared with a six-track system for both types of transition operation. Increase in track spacing from 30 nautical miles to 60 nautical miles in the four-track system arrangements (compare configurations C with D and E with F) results in only small increases in average fuel and penalties except for the average time penalty increase between configurations E and F for the superimposed transition procedure. (See fig. 13(b).) The larger time penalty increase for configuration F arises from the long subsonic cruise departure operation to the outer tracks with this transition procedure.

For the separate transition procedure operations with configuration A, the arrivals because they were on the outer tracks had to be routed through CYN to provide sufficient lateral separation from departures and to avoid conflicts of crossing descending and climbing traffic. This procedure results in longer arrival operations than with configuration B where the arrivals can be brought in through RVH. The result is that the average fuel, time, and distance penalties are higher in the configuration A operations than in the configuration B operations (fig. 10) and the spread in individual values is also greater. For the separate transition procedure, the results thus indicate that arrivals should preferably be handled on the inner tracks and departures on the outer tracks.

For the superimposed transition procedure operations (fig. 12) configuration A shows a slight advantage over configuration B in average fuel and distance penalties, and an appreciable advantage in the average time penalty. The larger time penalties for configuration B arise from the long subsonic cruise departure operations to the outer tracks. For the superimposed transition procedure, the results thus indicate that departures should be handled on the inner tracks and arrivals on the outer tracks.

Comparison of the preferred configurations for the two transition procedures, that is, configuration B with separated transition (fig. 10) and configuration A with superimposed transition (fig. 12), shows that the average penalties in fuel, time, and distance are only slightly different with the separated transition operations than with the superimposed transition operations. With such small differences in penalties, choice of the preferred transition procedure in the New York area would appear to depend on evaluation of the airspace available and on the preferred transition procedures for the departure and arrival track allotments at the European end of the track system.

SUMMARY OF RESULTS

The results of an analytical investigation of two departure and arrival transition procedures between John F. Kennedy International Airport and projected North Atlantic track systems for supersonic transport (SST) operations have been presented. The procedures studied were (1) separated departure and arrival transition routes with departures made at supersonic speeds, and (2) superimposed departure and arrival transition routes with departures restricted to subsonic speed until the airplane is on the track system. For both procedures, transition routes with intercept angles from 30° to 90° to both six- and four-track systems were investigated. Track spacings of 30 and 60 nautical miles were studied. The principal results in terms of the penalties in fuel, time, and distance are

1. Transitions at the shallowest intercept angles provided the smallest average (system) penalties in fuel and distance for both types of transition procedures.

2. On a systems basis, separated departure and arrival transition procedures provided smaller time penalties than superimposed departure and arrival transition procedures.

3. Variations between four- and six-track systems and 30- and 60-nautical-mile track spacings had, in general, only small effects on the fuel and time penalties.

4. For the separated departure and arrival transition route procedure, the least penalties on the average were found when arrivals were handled on the inner set of tracks and the departures on the outer set of tracks.

5. For the superimposed departure and arrival transition route procedure, the least penalties on the average were found when departures were handled on the inner set of tracks and the arrivals on the outer set of tracks.

6. For the preferred methods of departure and arrival track allotment noted in results 2 and 3, the average penalties with the separated transition procedure were only slightly different than those with the superimposed transition procedure. Choice of the transition procedure in the New York area would thus appear to depend on consideration of airspace availability and on the preferred departure and arrival track allotments at the European end of the track system.

Langley Research Center,
National Aeronautics and Space Administration,
Hampton, Va., April 27, 1972.

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2. Sawyer, Richard H.; Silsby, Norman S.; and McLaughlin, Milton D.: Simulation Studies of the Supersonic Transport in Future Air Traffic Control Systems. NASA TN D-4944, 1968.

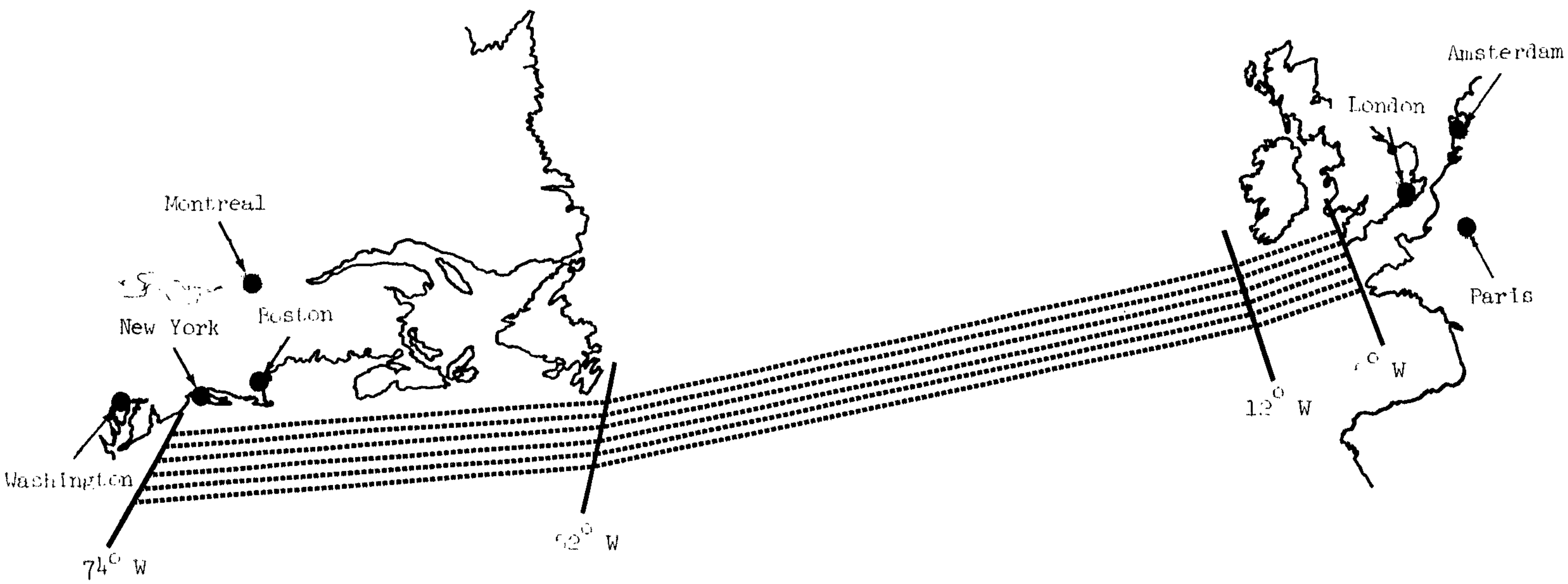


Figure 1.- Example of transatlantic supersonic transport track system.

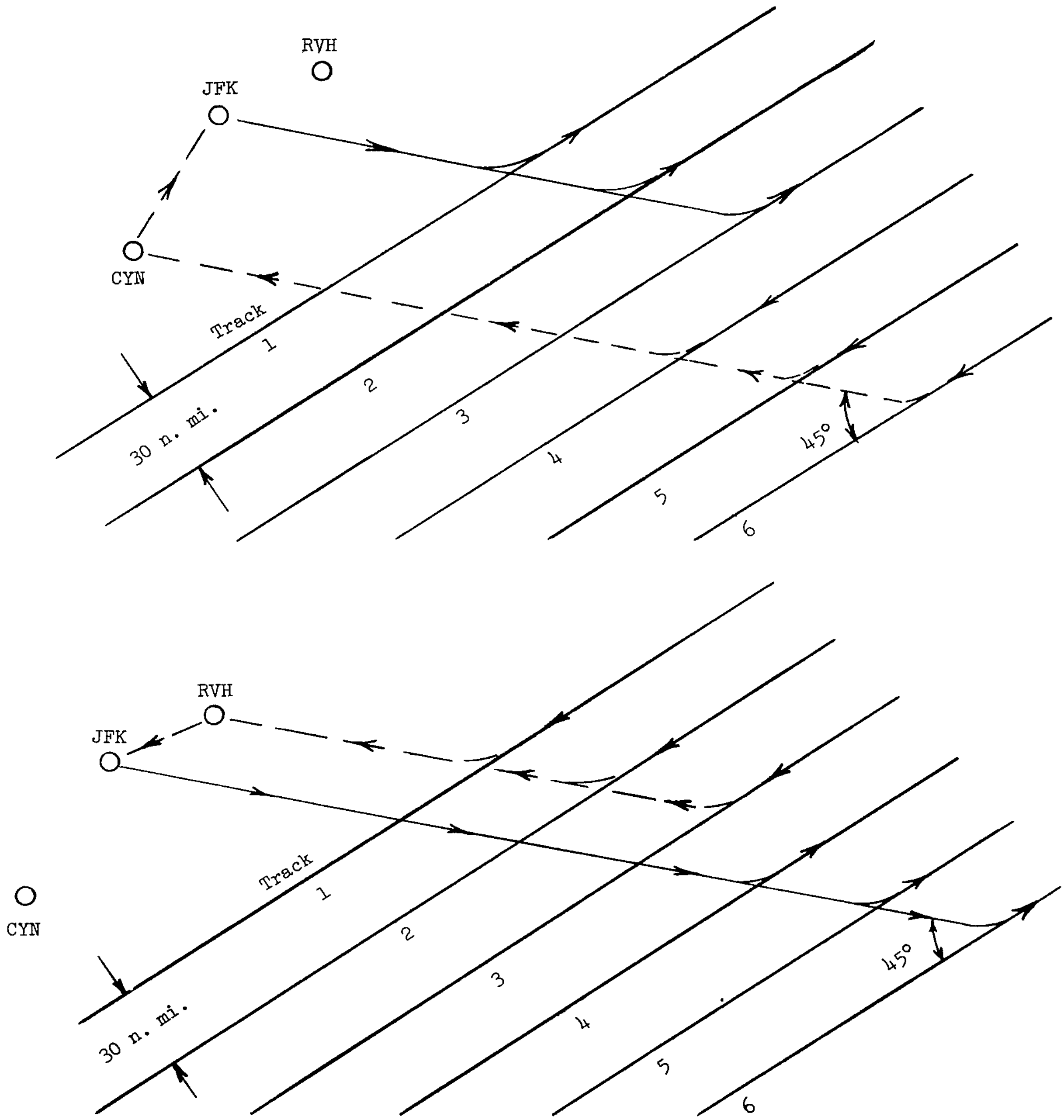


Figure 2.- Example of separated departure and arrival transition routes.

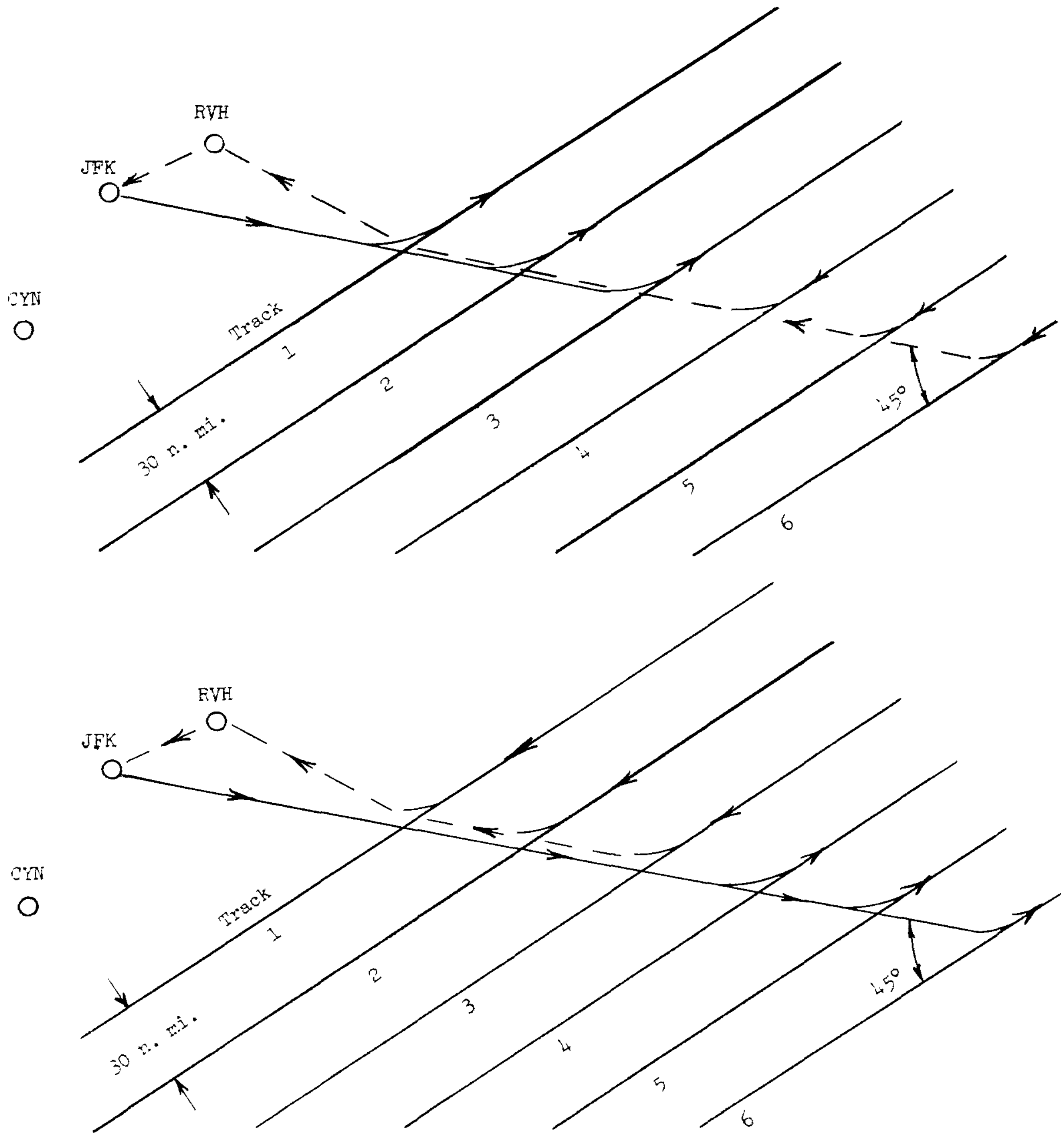


Figure 3.- Example of superimposed departure and arrival transition routes.

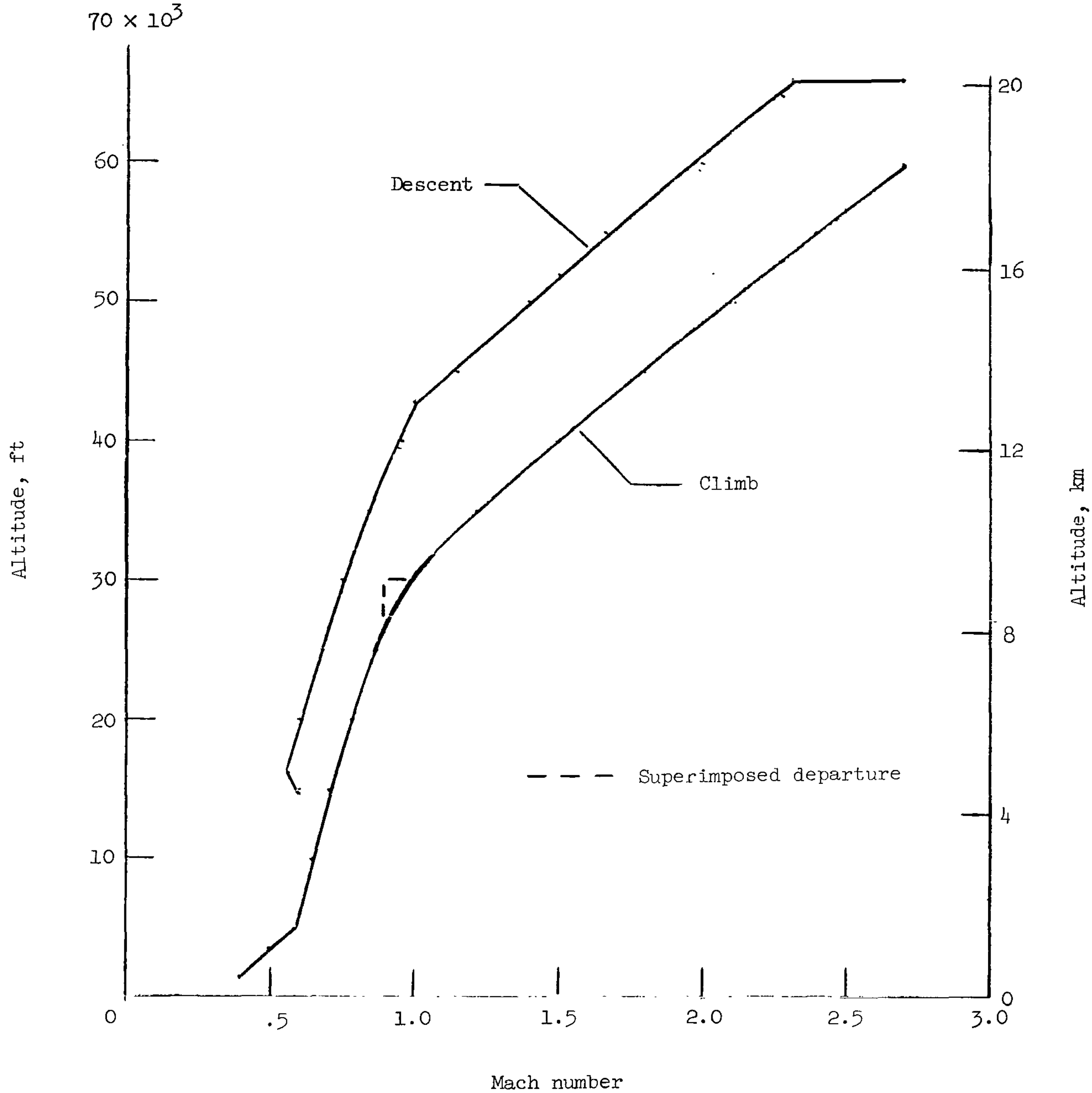
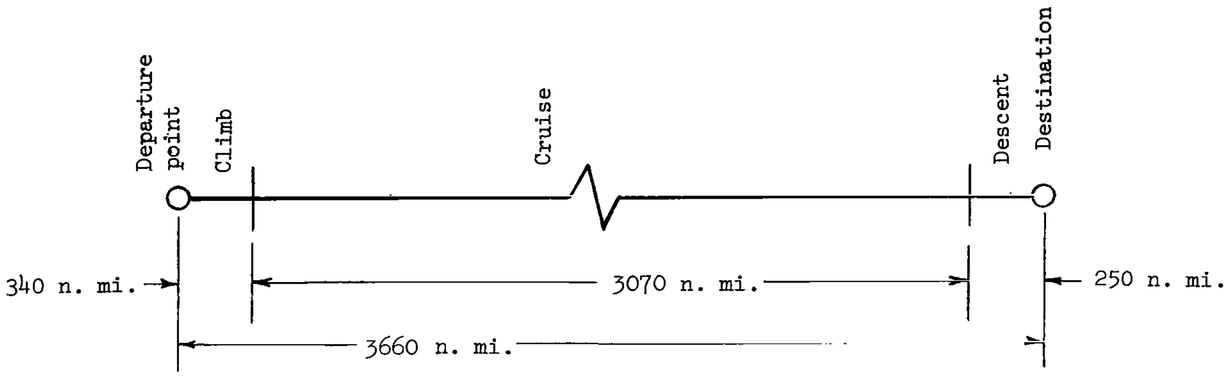
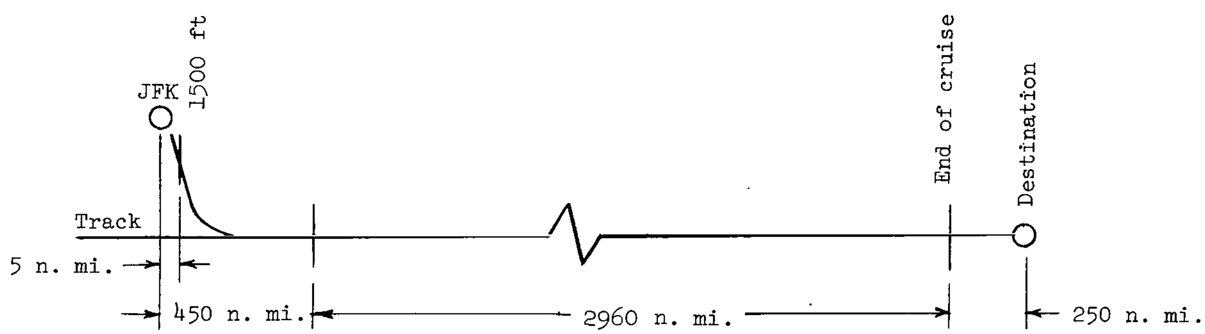


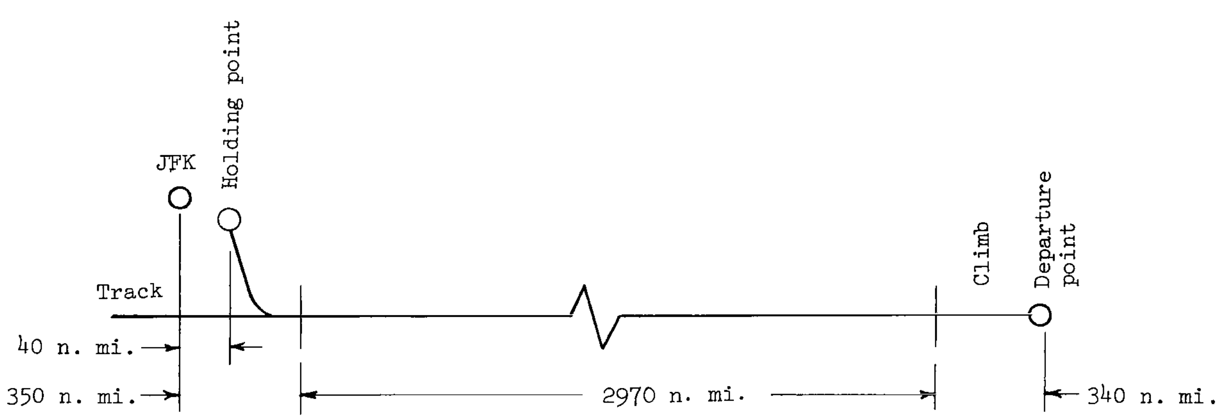
Figure 4.- Climb and descent schedules.



(a) Mission.

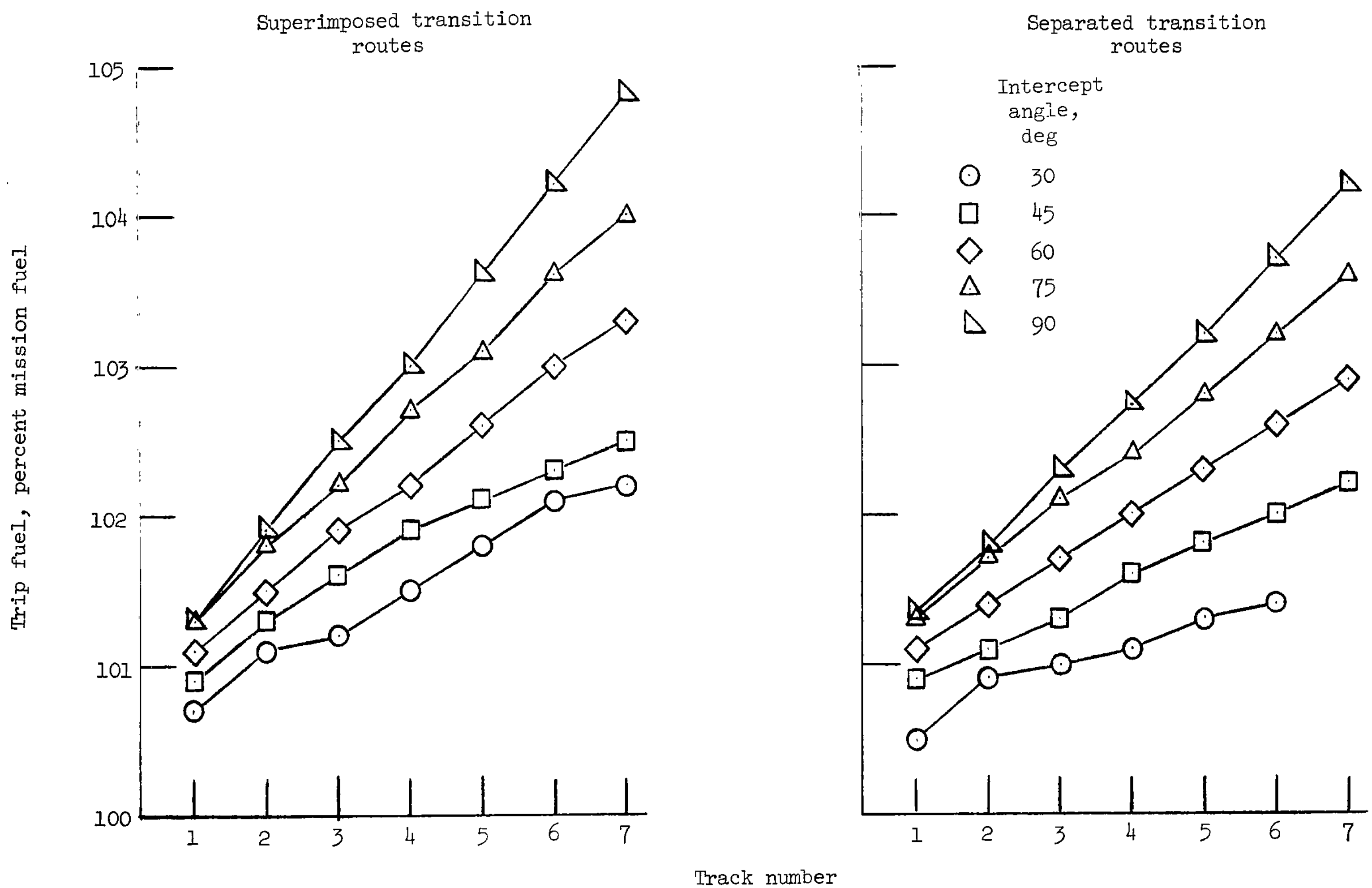


(b) Typical departure trip.



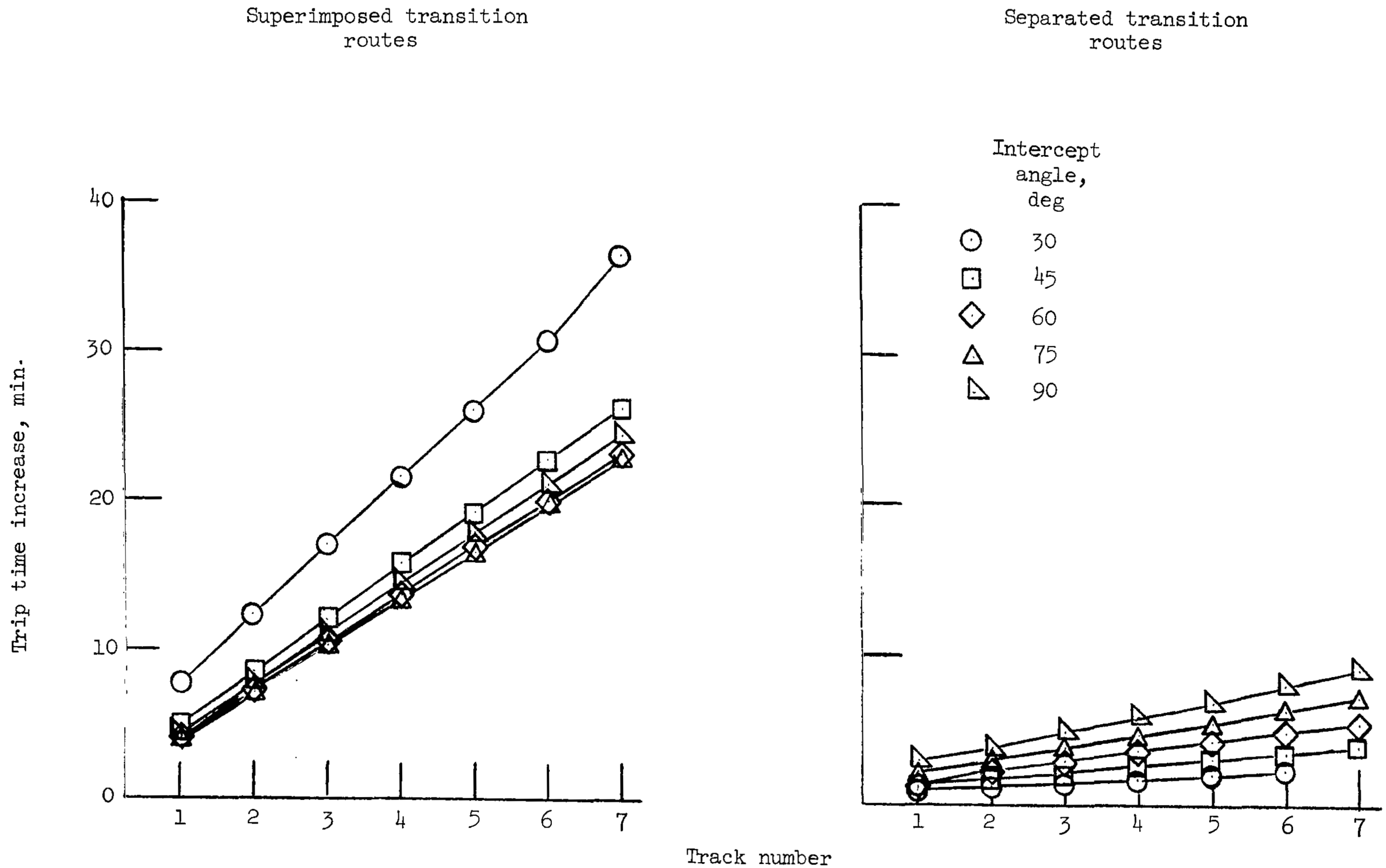
(c) Typical arrival trip.

Figure 5.- Mission and trip definitions.



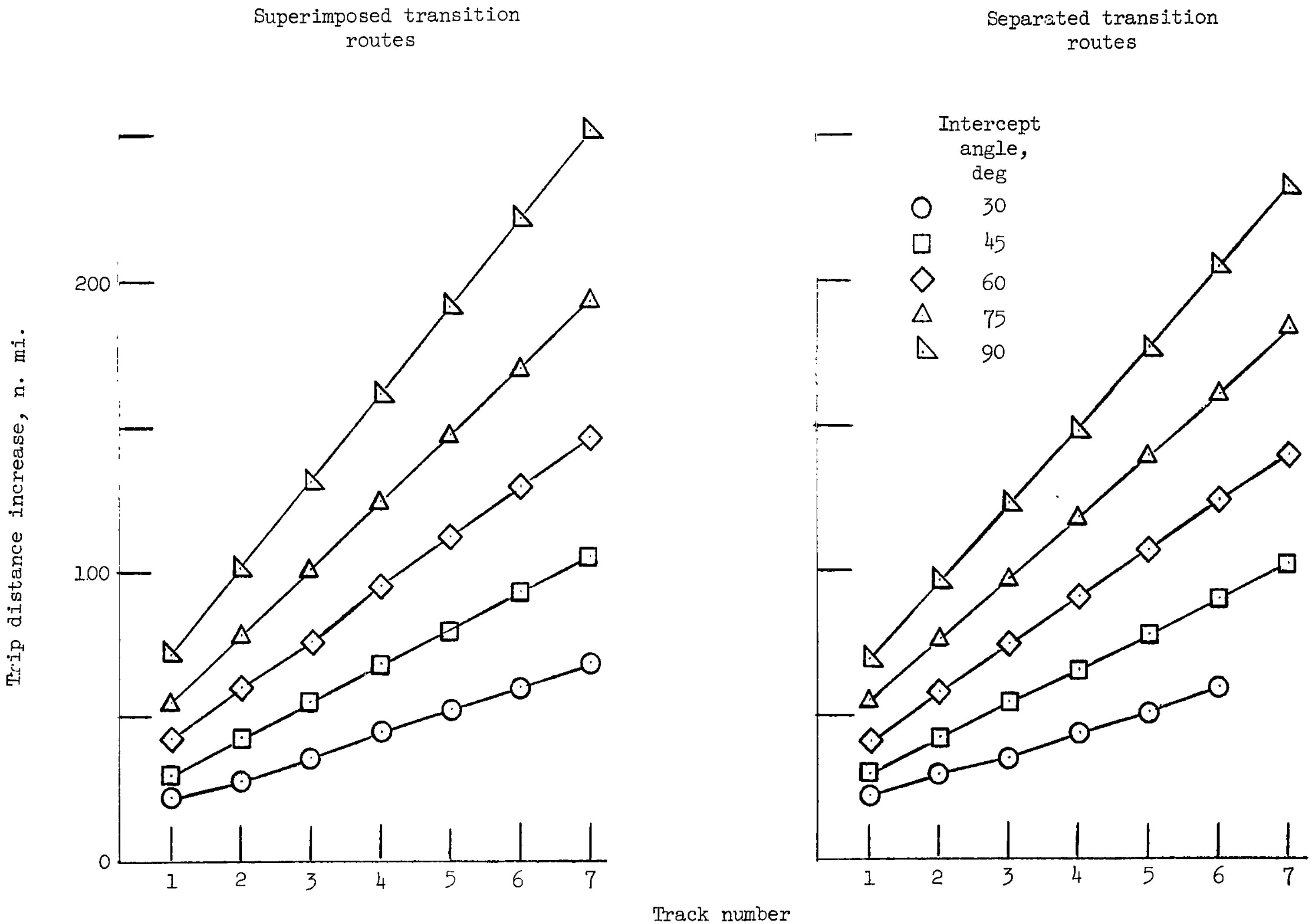
(a) Trip fuel.

Figure 6.- Comparison of fuel, time, and distance for departures on superimposed and separated departure and arrival transition routes.



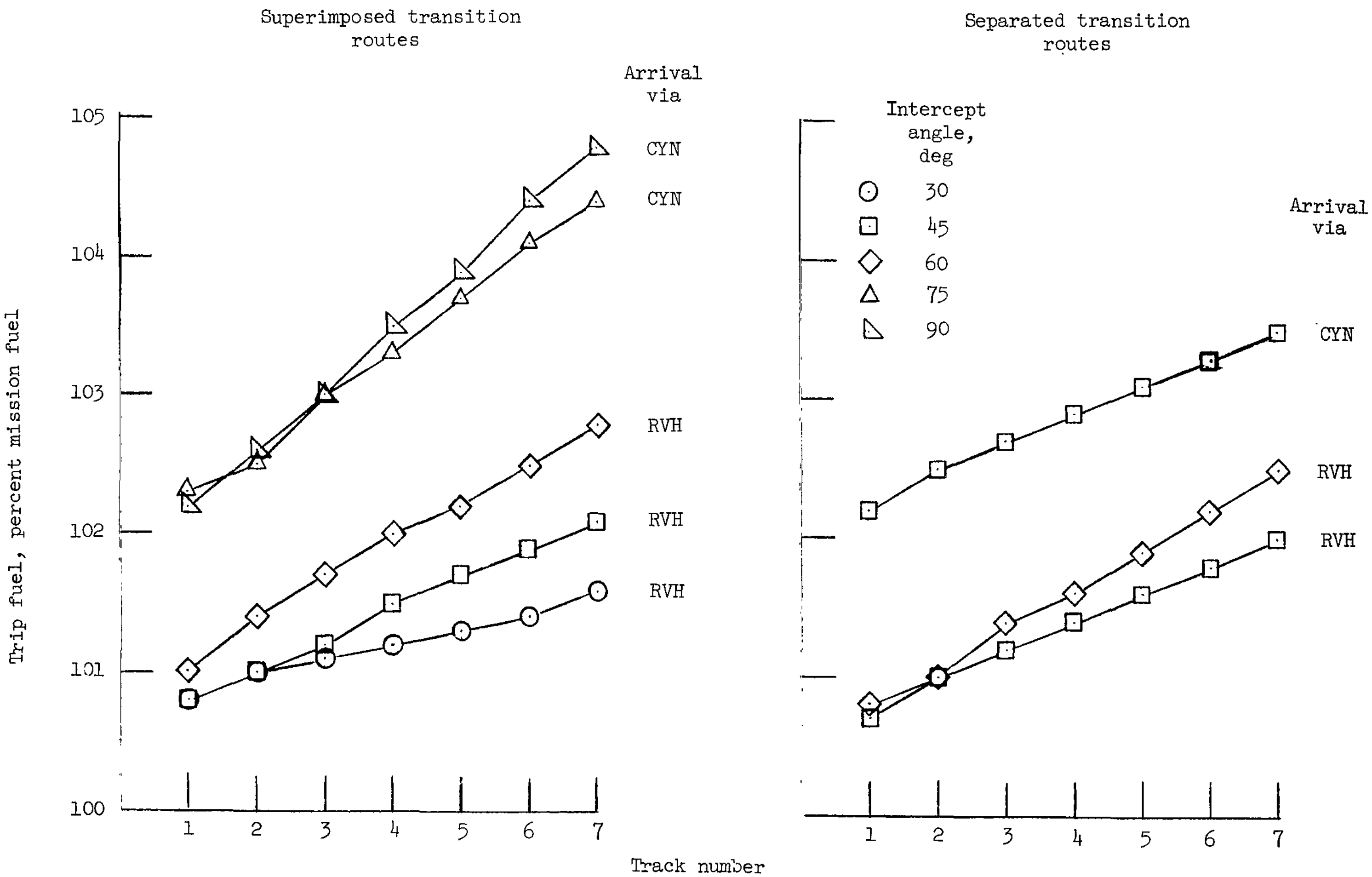
(b) Trip time increase.

Figure 6.- Continued.



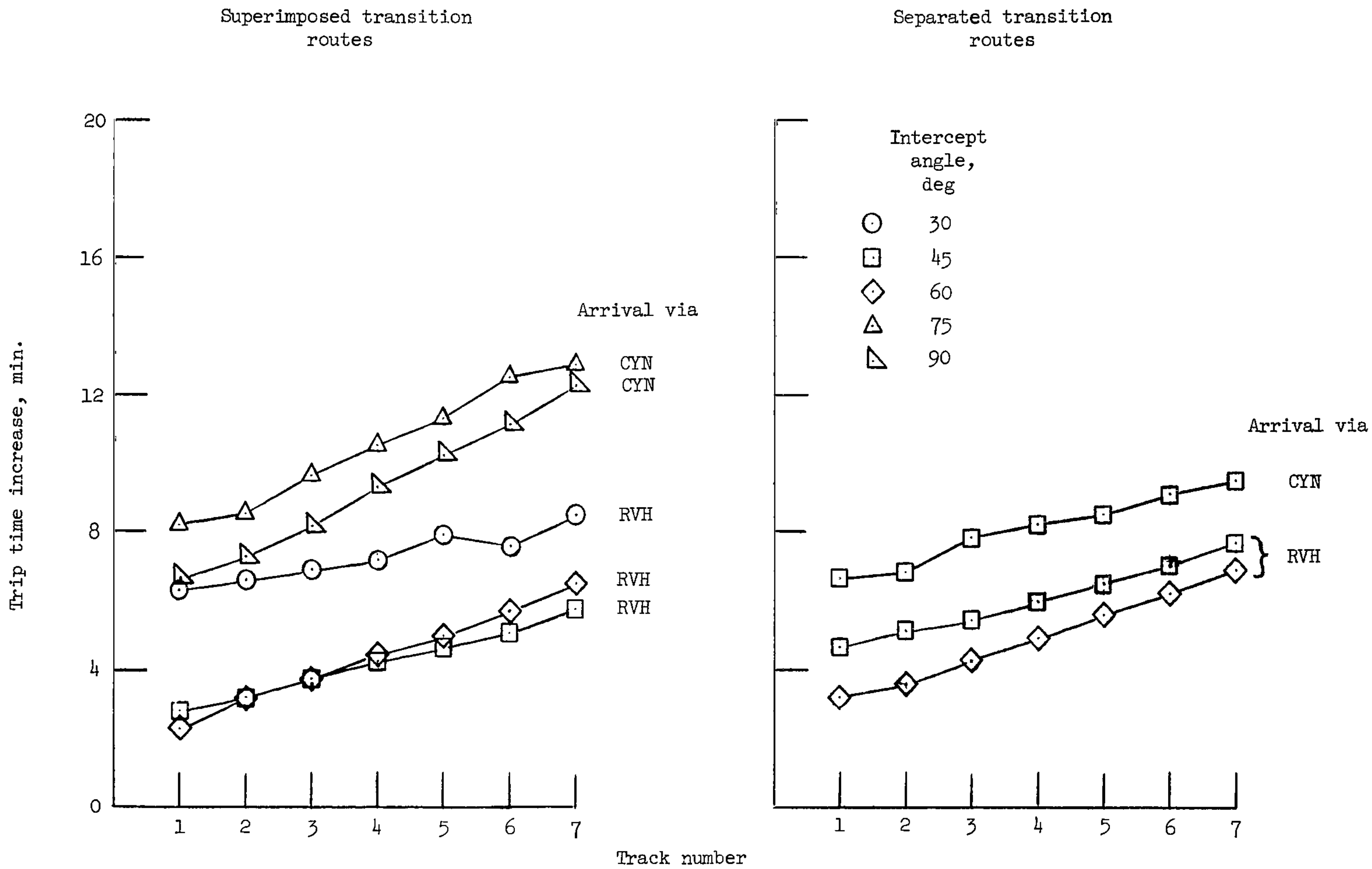
(c) Trip distance increase.

Figure 6.- Concluded.



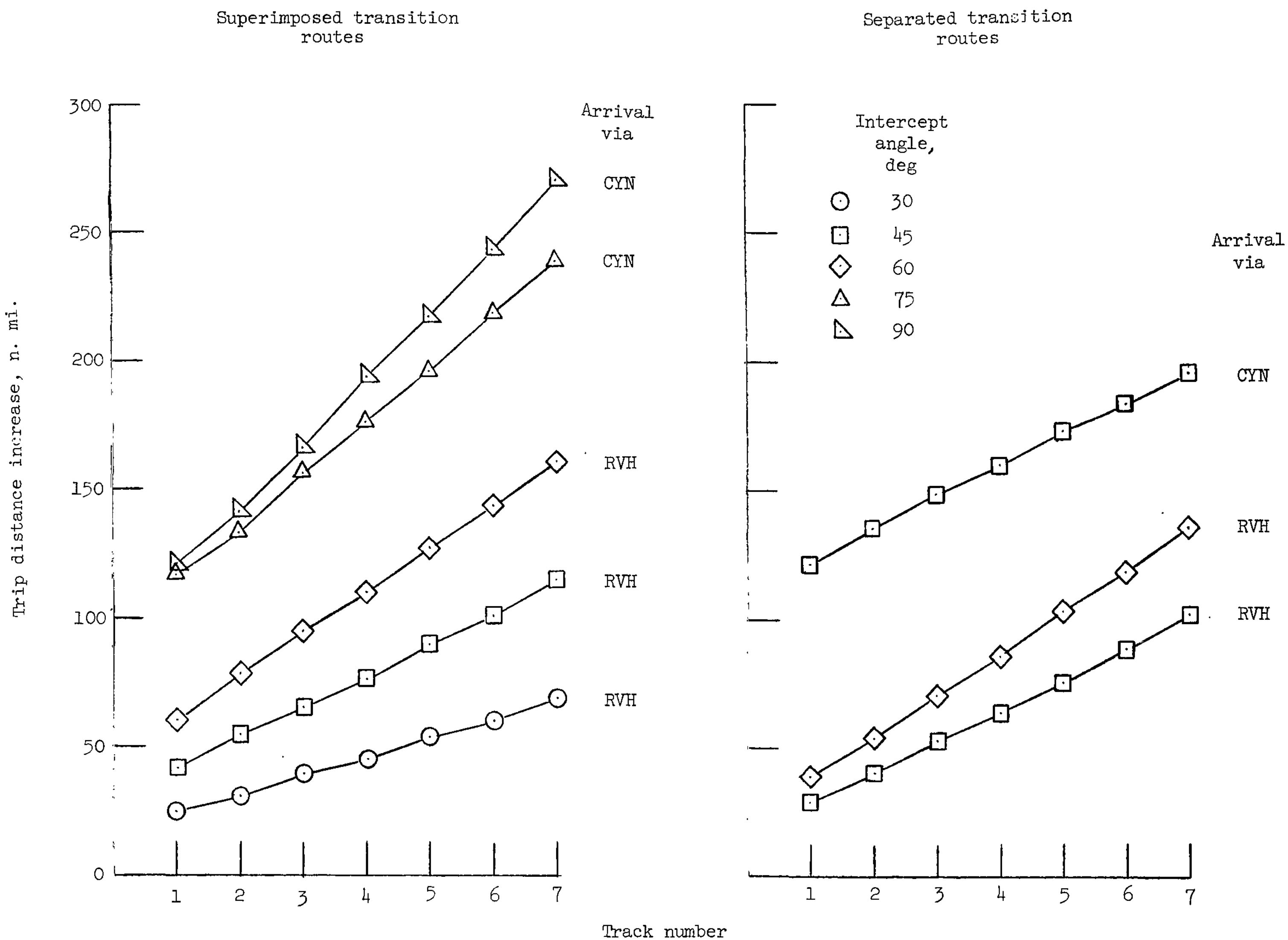
(a) Trip fuel.

Figure 7.- Comparison of fuel, time, and distance for arrivals on superimposed and separated departure and arrival transition routes.



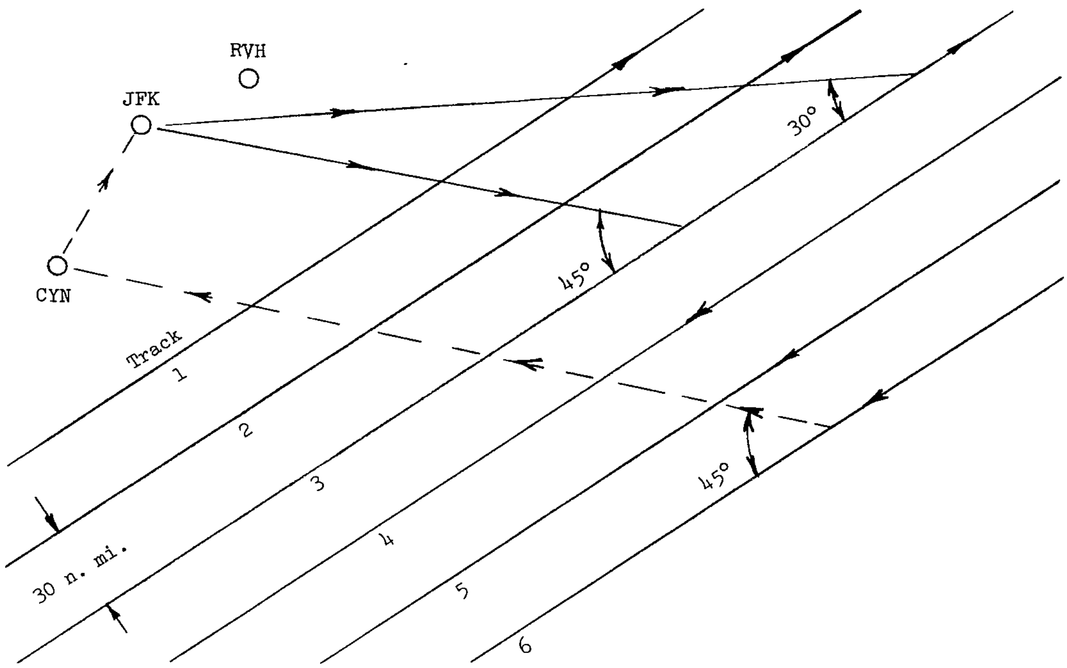
(b) Trip time increase.

Figure 7.- Continued.

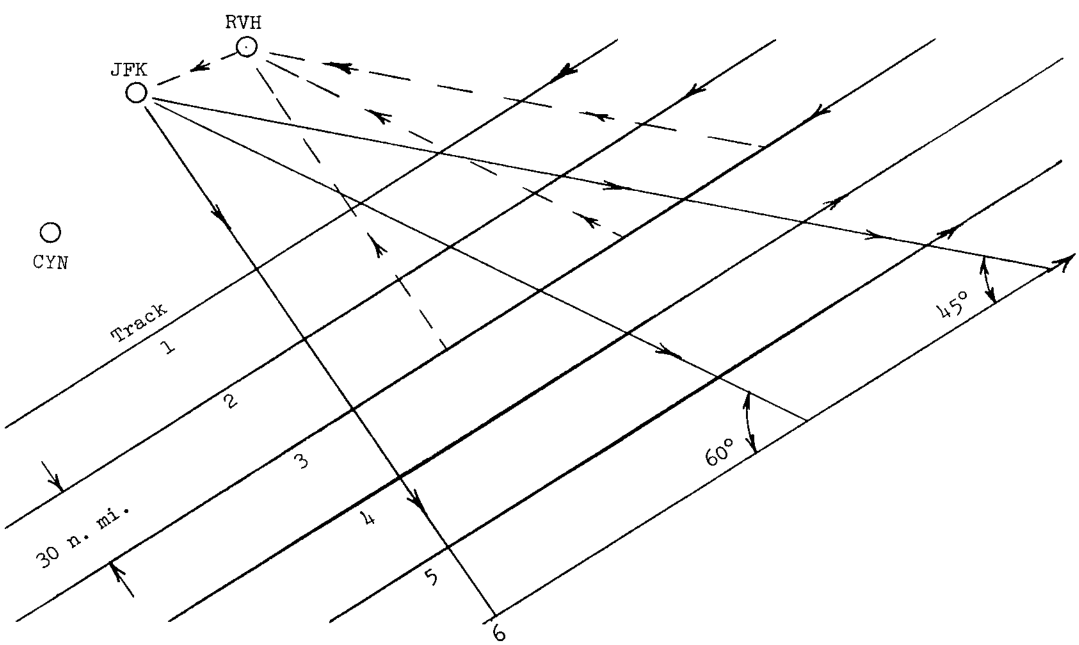


(c) Trip distance increase.

Figure 7.- Concluded.

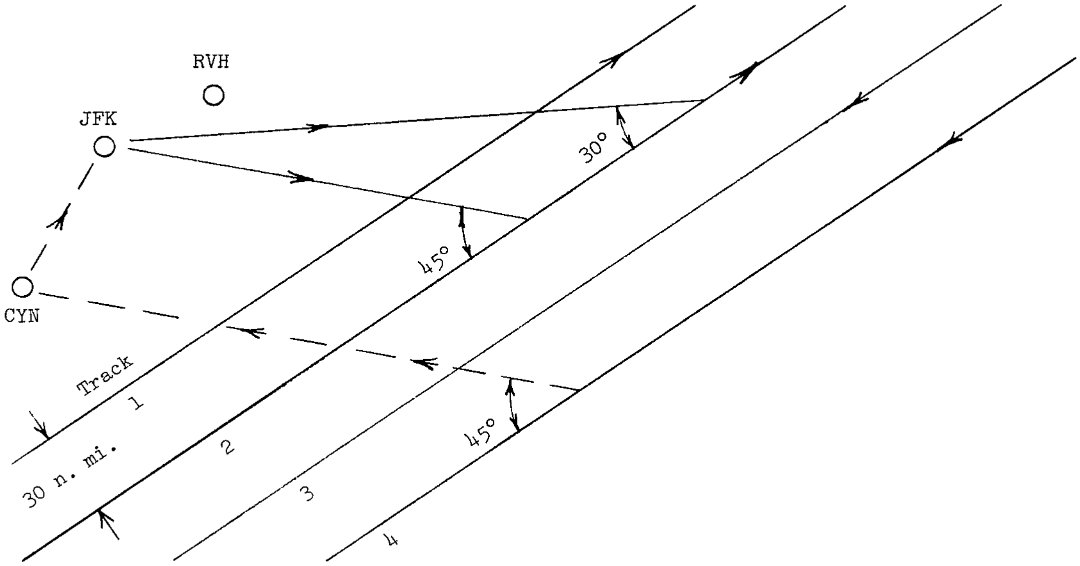


(a) Configuration A.

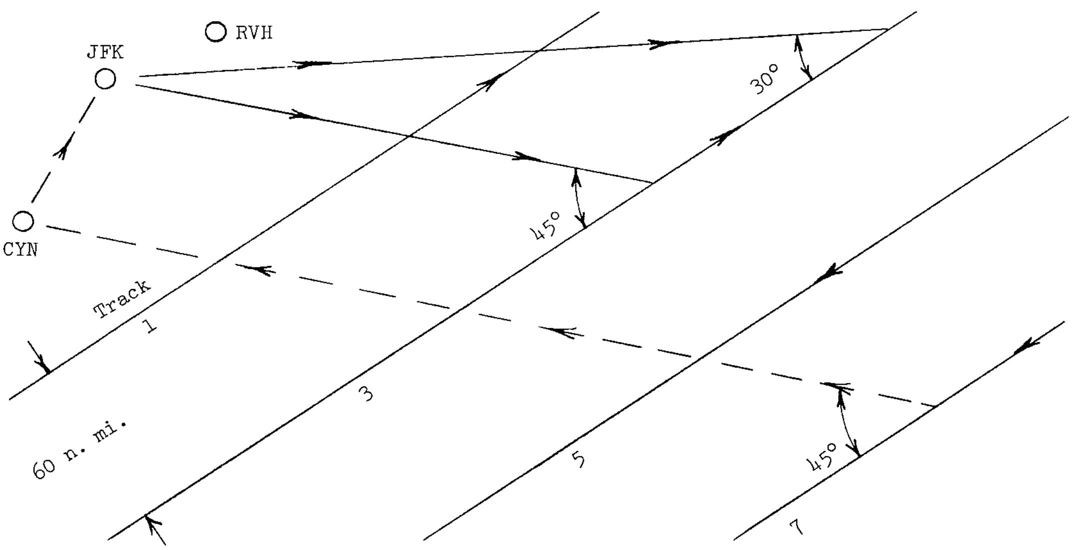


(b) Configuration B.

Figure 8.- Separated departure and arrival transition routes with 30°, 45°, 60°, and 90° intercept angles.

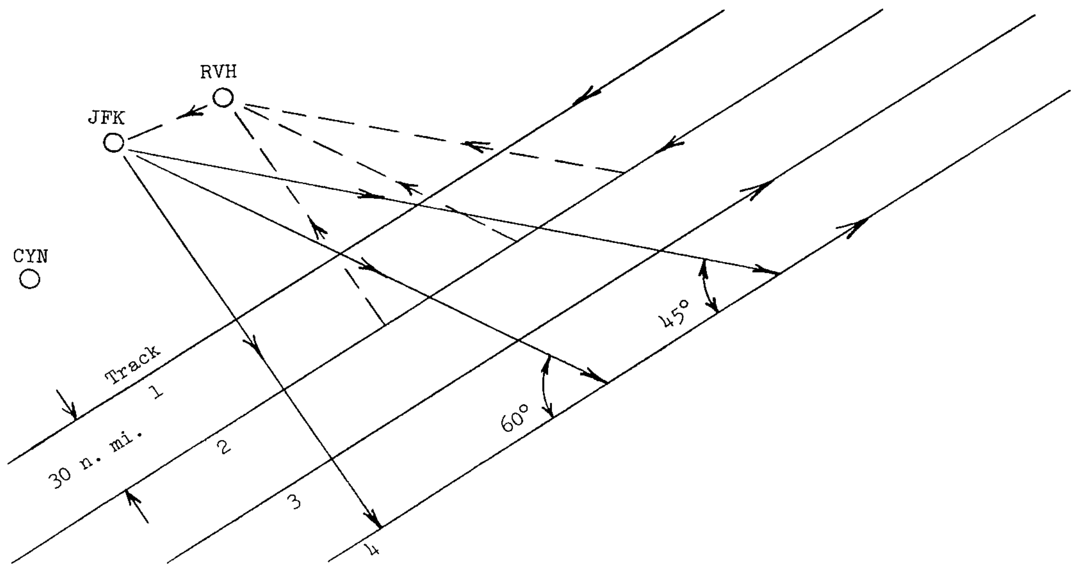


(c) Configuration C.

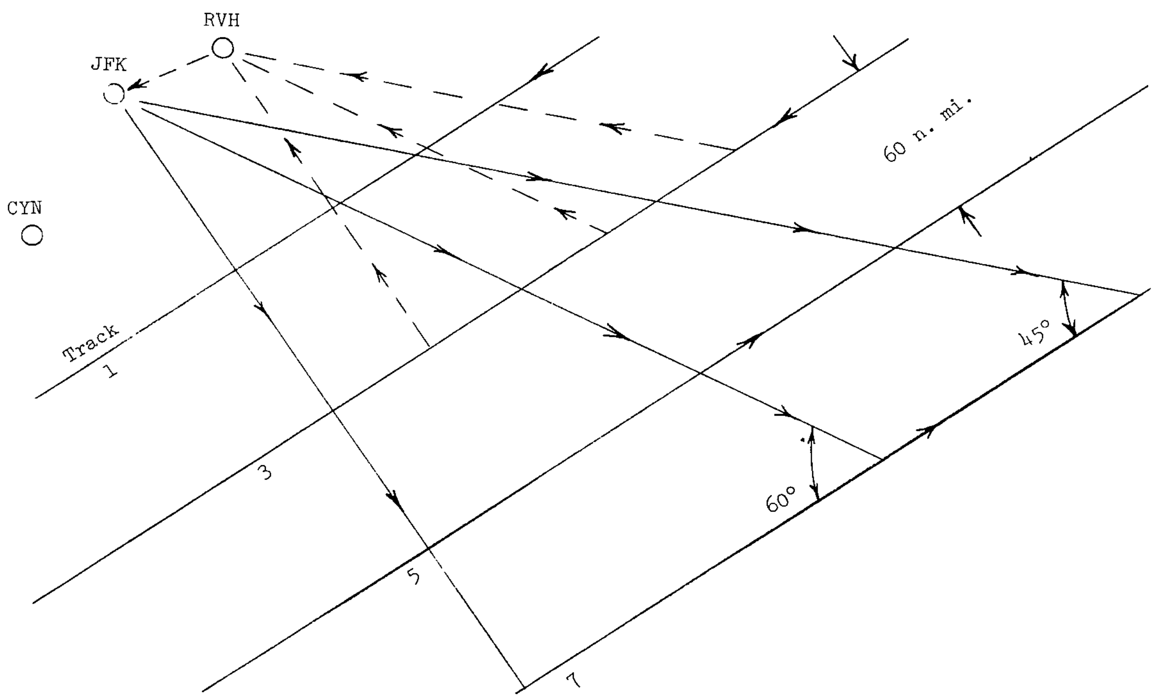


(d) Configuration D.

Figure 8.- Continued.

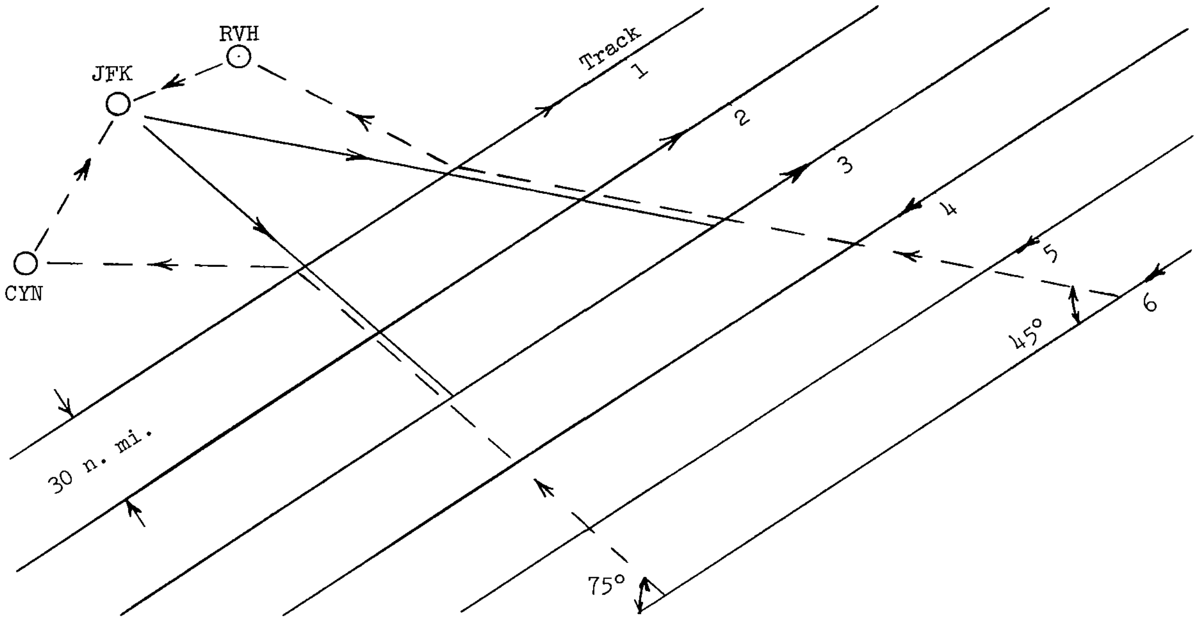


(e) Configuration E.

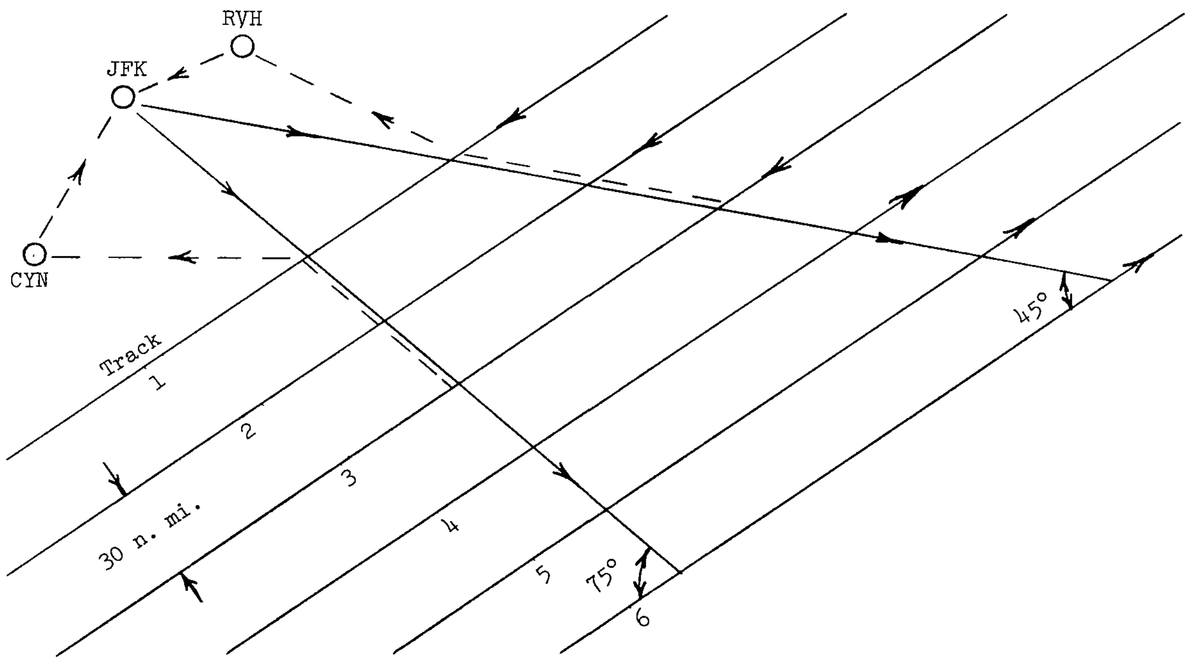


(f) Configuration F.

Figure 8.- Concluded.

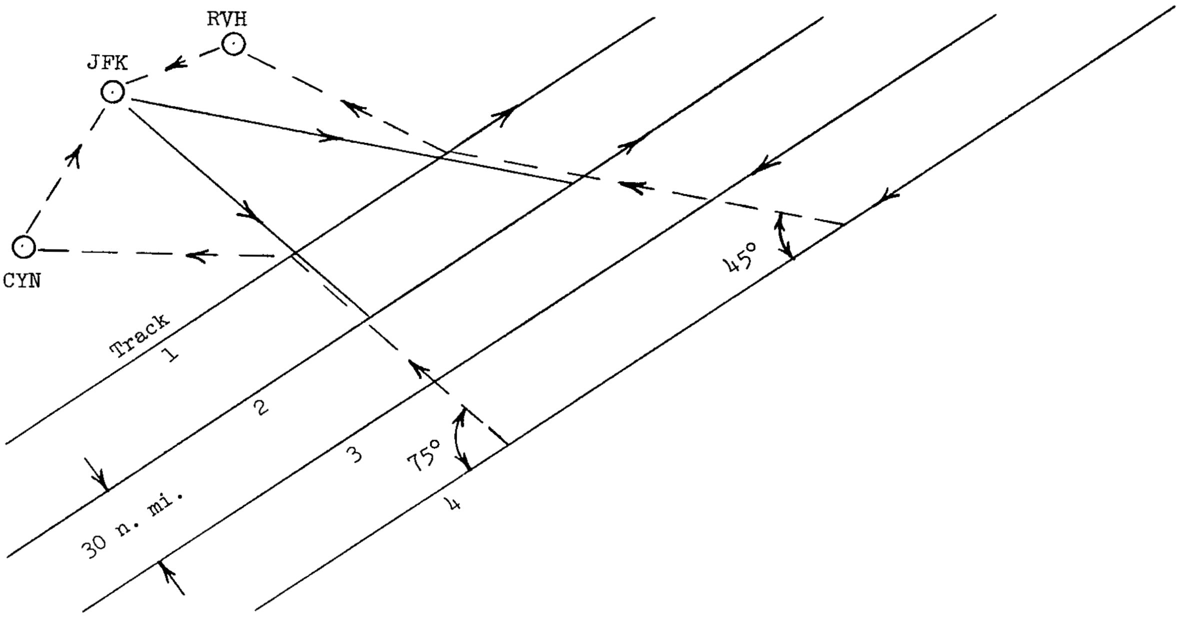


(a) Configuration A.

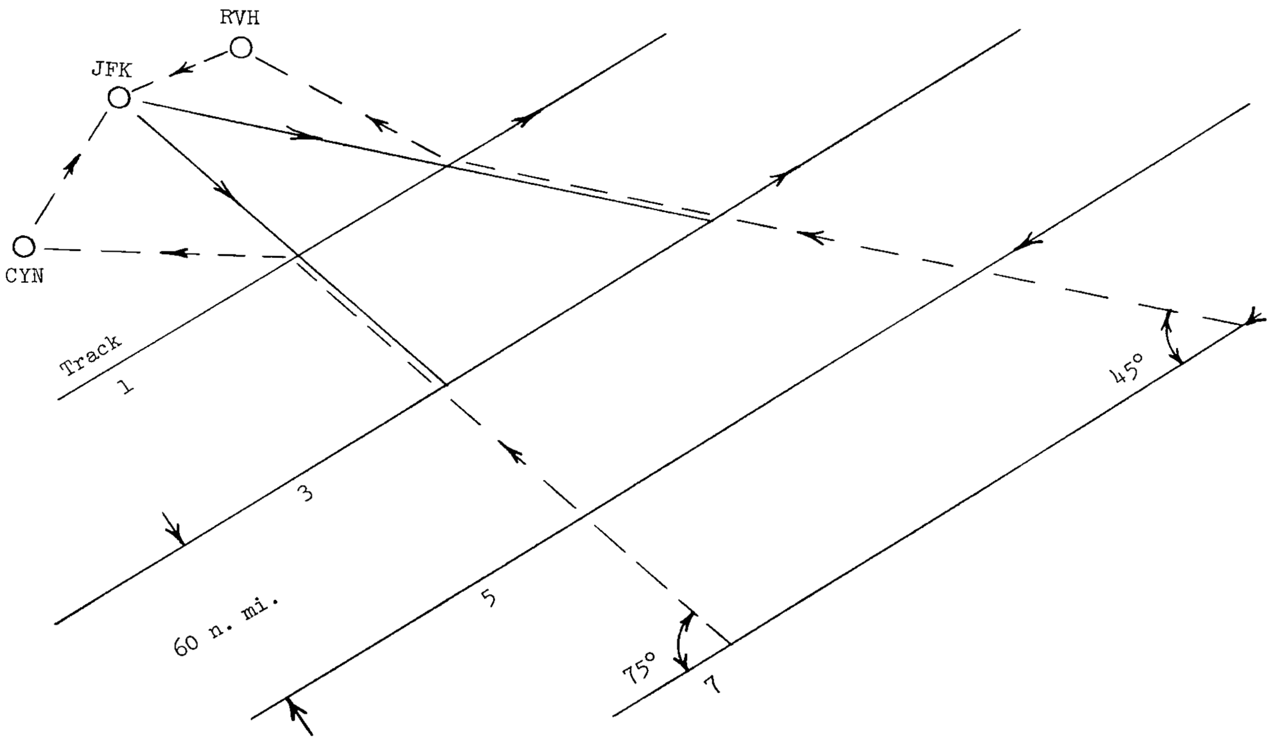


(b) Configuration B.

Figure 9.- Superimposed transition routes at 45° and 75° intercept angles. Calculations also made at 30°, 60°, and 90° intercept angles.

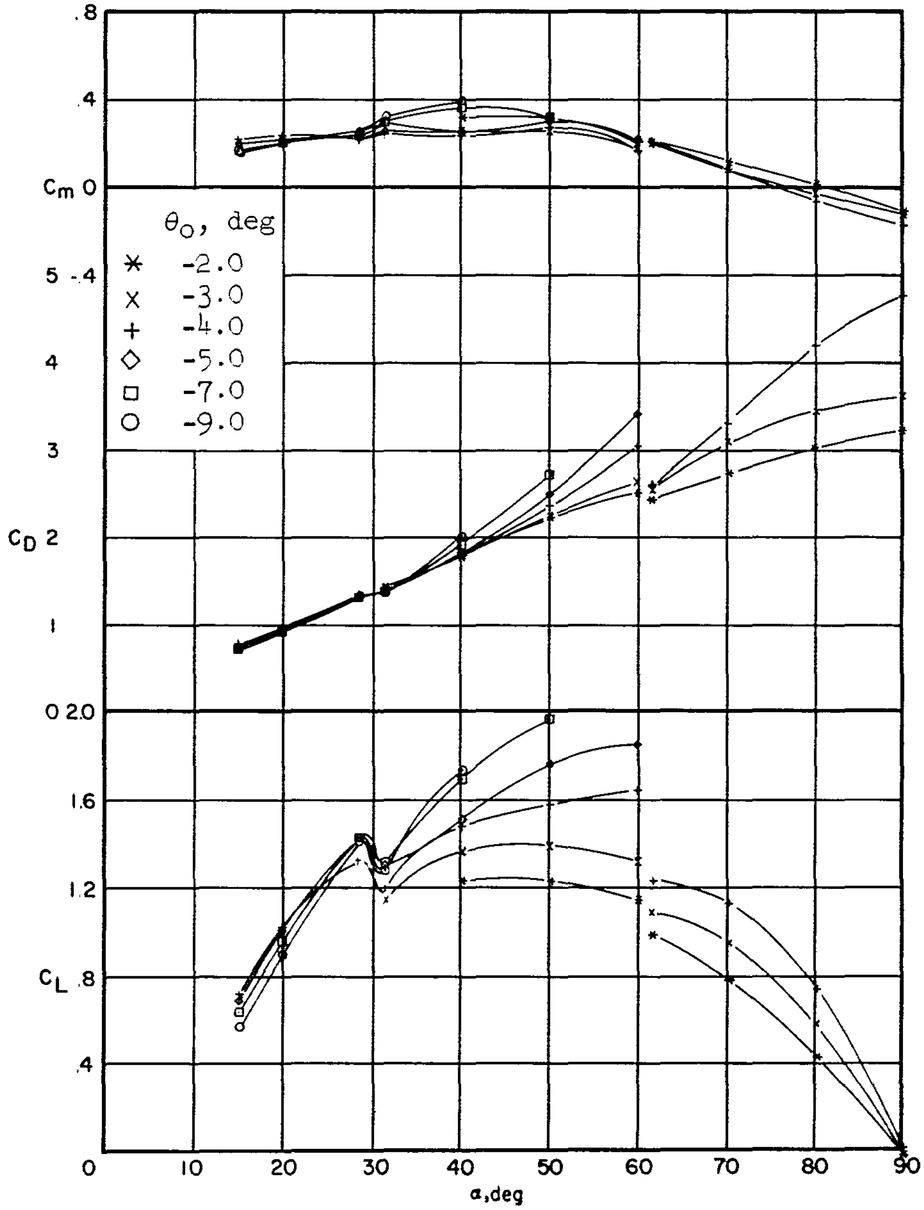


(c) Configuration C.



(d) Configuration D.

Figure 9.- Continued.



(b) $M_\infty = 0.7$

Figure 11.- Continued.

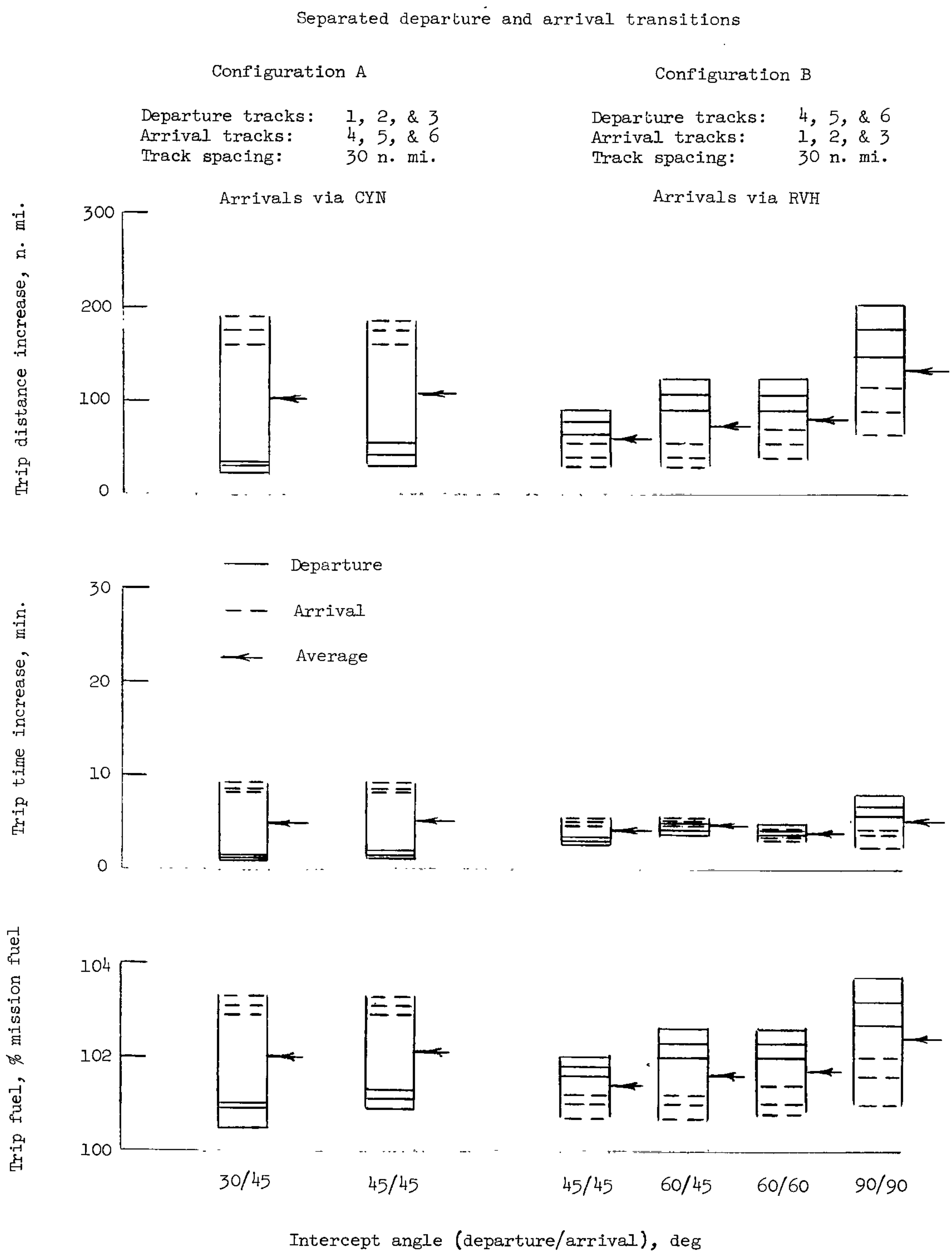
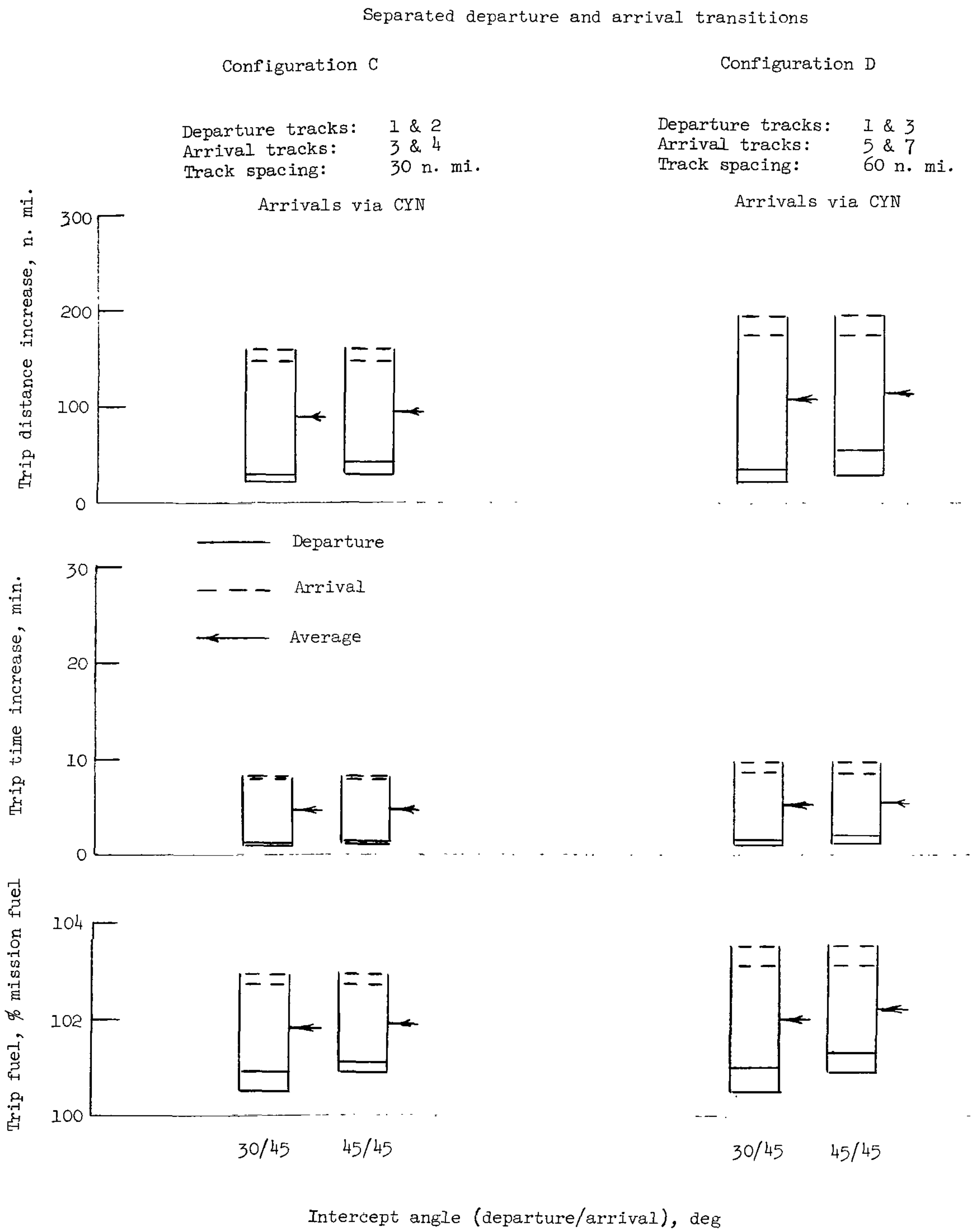
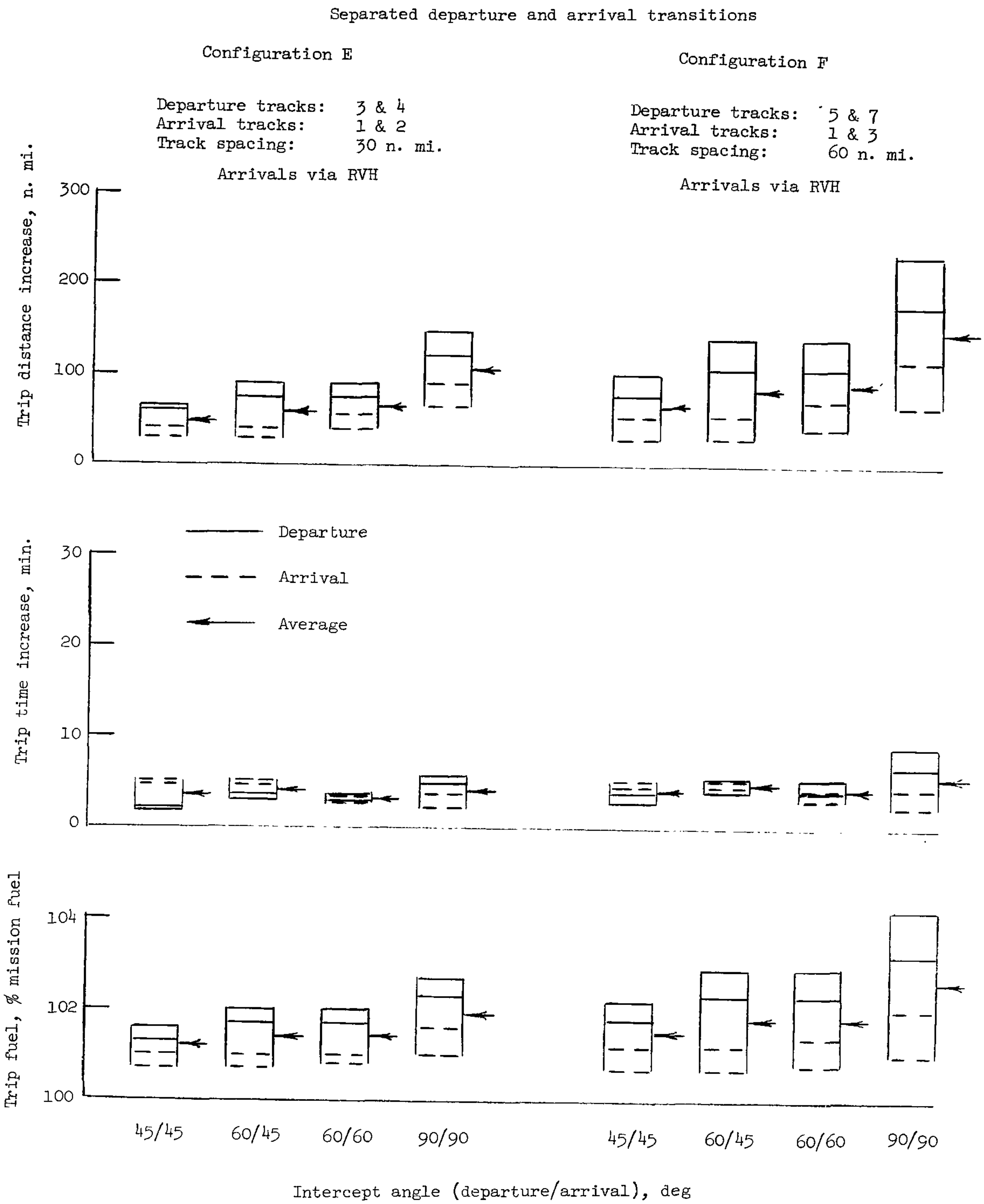


Figure 10.- Comparison of fuel, time, and distance for track configurations A and B at several departure and arrival transition-track angle combinations. Separate departure and arrival transition routes; six-track system; 30-nautical-mile track spacing.



(a) Configurations C and D.

Figure 11.- Comparison of fuel, time, and distance for track configurations C, D, E, and F at several departure and arrival transition-track angle combinations. Separated departure and arrival operations; four-track system; 30- and 60-nautical-mile track spacings.



(b) Configurations E and F.

Figure 11.- Concluded.

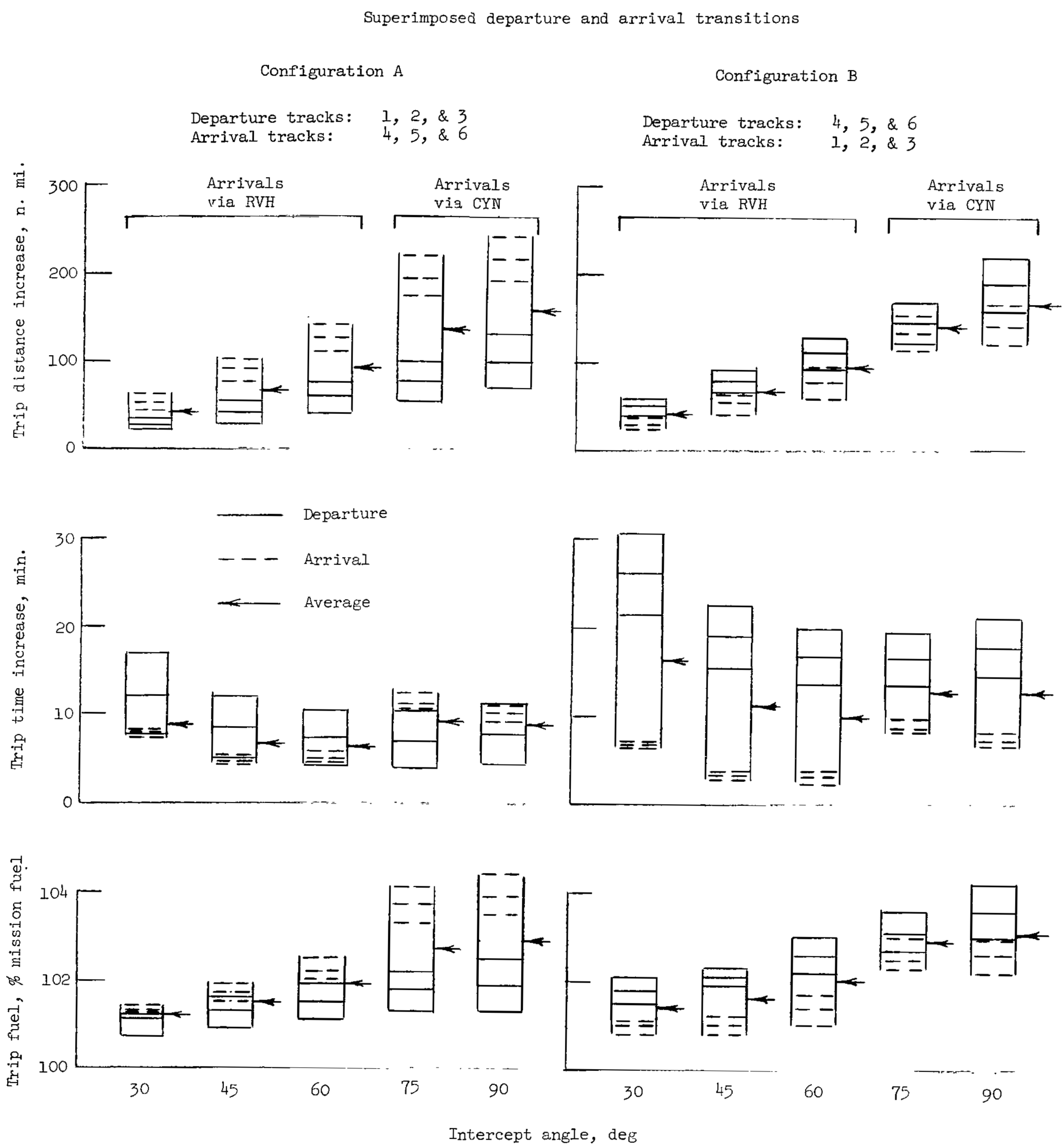
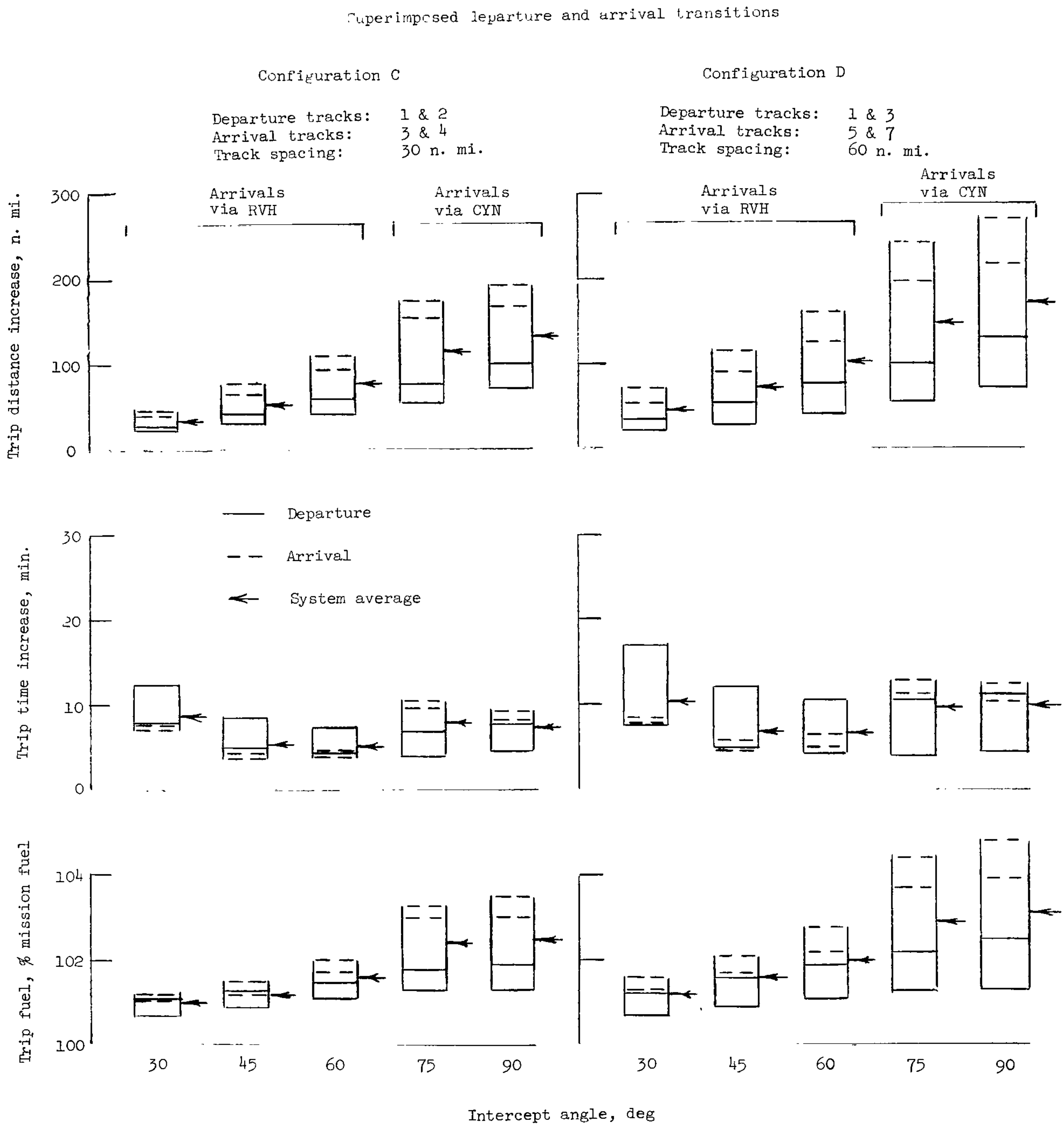
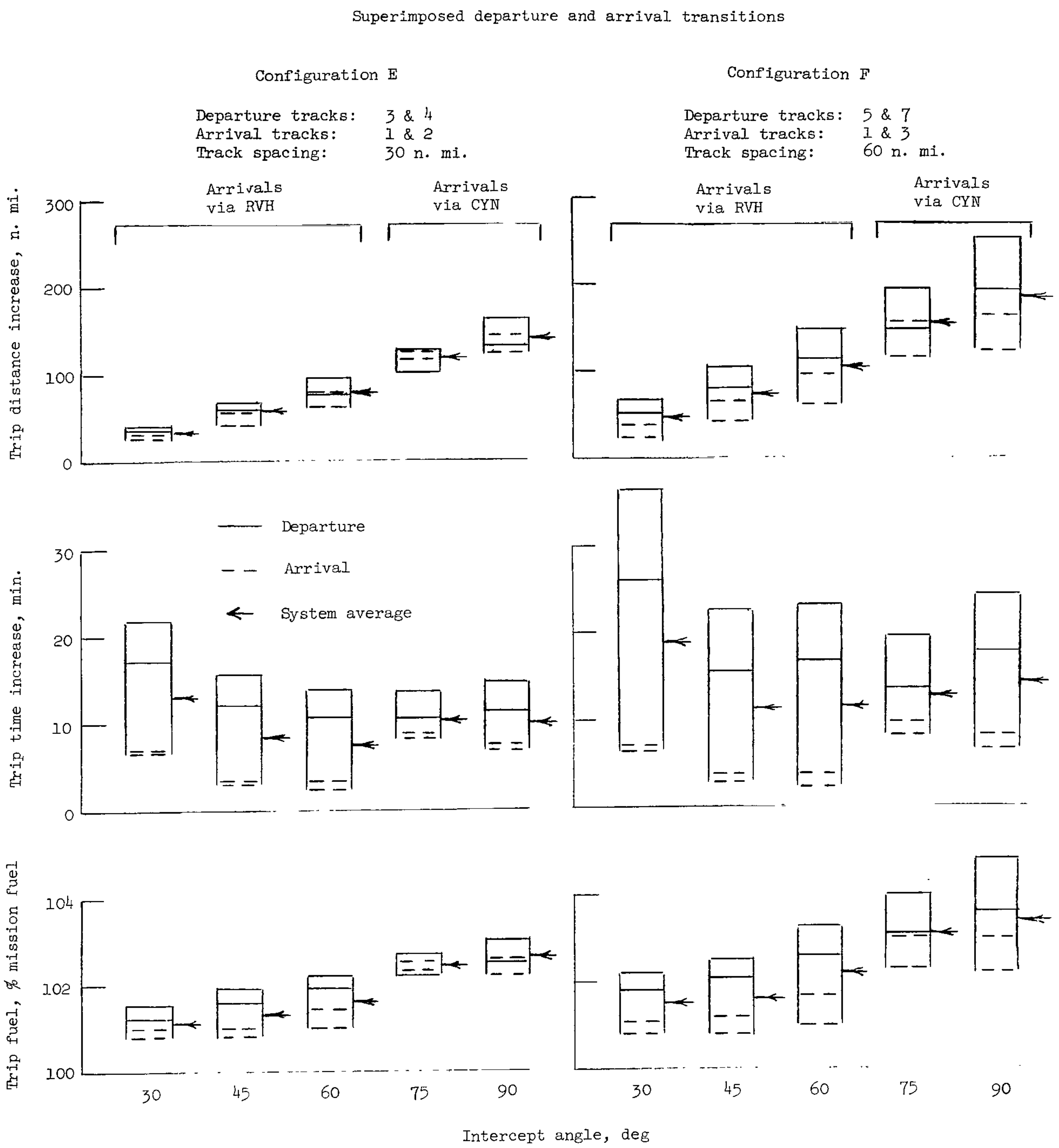


Figure 12.- Comparison of trip fuel, time, and distance for track configurations A and B at five transition-track intercept angles. Superimposed departure and arrival transition routes; six-track system; 30-nautical-mile track spacing.



(a) Configurations C and D.

Figure 13.- Comparison of fuel, time, and distance for track configurations C, D, E, and F at five transition-track intercept angles. Superimposed departure and arrival transition routes; four-track system; 30- and 60-nautical-mile track spacings.



(b) Configurations E and F.

Figure 13.- Concluded.

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—NATIONAL AERONAUTICS AND SPACE ACT OF 1958

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