The F-104 Starfighter is a product of the California Division of the Lockheed Aircraft Corporation. Its general configuration, which is unique among aircraft or missiles of which details have been revealed, was revealed in the spring of 1956. Our issue of April 20 of that year contained an extensive dissertation upon the general design of the aircraft, together with an outline of its history and basic characteristics. It is not proposed to go over any of this ground again; but, given the F-104 as an entity in being, it is now possible to comment upon much of its structural and engineering design which was previously classified as secret.

In the design of the wings Lockheed faced a particularly acute set of problems. The thickness/chord ratio of 3.4 per cent accentuated the difficulties inherent in driving powered ailerons and flaps—particularly when they are the assertions of a publicity-conscious commercial company. It is, therefore, appropriate that this first full description of the Lockheed F-104 should appear at a time when its performance has been demonstrated by officially observed flights which promise to bring to the world the speed and altitude—the first time in history that both records have been held by the same type of airplane. The submitted figures are: altitude, 91,249 ft; speed, 1,404.19 m.p.h. (about Mach 1.5)...

Blowing starts as soon as the flap angle reaches 15 deg, and is progressively increased until the system is at full throttle when the flaps reach their full deflection of 45 deg. Under normal conditions the flow velocity through the slots is completely supersonic at 2,300 ft/sec; the system reduces the stalling speed by from 12 to 17 kt and the landing run by some 25 per cent, a typical touch-down speed for an operational 104 being 135 kt. As was explained in our issue of April 20, 1956, the horizontal tail is mounted at the top of the squat fin. Both surfaces are built, like the wing, with heavy skins and relatively simple interiors. In addition a 5 ft-long ventral stabilizing fin is fitted. The horizontal tail is pivoted aft of mid-chord and is driven by the actuator in the forepart of the fin. To it is attached the upper rear part of the vertical surface, which slides partially inside the forward portion of the fin-tip as the horizontal tail assumes a negative angle of incidence. Early flight-testing revealed that the 104 could, at extreme speed and altitude, enter a super-stalled condition leading to uncontrollable pitch-up. To counter this angle-of-attack sensing unit was incorporated, which first causes stick-shake and then, should the pilot persist in pulling back, reverses the movement of the horizontal tail. The 104 is fitted with a fully transistorized three-axis autostabilizer, by Lear, Inc.

Heart of the aircraft is its powerplant. It is remarkable that as far as one can tell—neither the U.S.A.F. nor Lockheed have made any effort to fit the F-104 with a rocket motor. Sole means of propulsion remains the General Electric J79 turbojet, with afterburner—which, it must be admitted, is an exceptionally fine powerplant. Some notes on the J79 appear on page 731 of this issue. It is well suited to flight at Mach numbers up to about 2.5, and in (Continued on page 742, after double-page drawing of the F-104).
LOCKHEED F-104A STARFIGHTER . . .

1. Erosion-resistant dielectric nose, rail-mounted for access
2. Nose mounting runners
3. Packaged ASC-14 fire-control unit
4. Radar cooling air supply
5. Cooling air outlet
6. Bottle camera
7. Radar gunight
8. One-piece casting below windscreen
9. Retracting shroud
10. Radar scope
11. Angle of attack vane
12. Rear-view mirror
13. Downward-ejecting seat
14. Servicing and escape hatch
15. Radar aerial
16. Steerable nose undercarriage
17. Mechanical door linkage
18. Taxiing lamps
19. Air start louvres
20. Gun blast tube
21. Six-barrel 1:171-63 gun (20 mm)
22. Ammunition feed chute
23. Ammunition compartment
24. Ammunition tank
25. Case ejection chute
26. Gun drive motor
27. Recall shock mountings
28. Floor to electronics and ammunition compartments
29. Supply and circuit-breaker box
30. Common shock-mounted electronics housing
31. "Jeep-can" electronics, cooled through rack supply
32. Flush aerial
33. Access to tank booster pump
34. Ram-driven emergency hydraulic pump and alternator
35. Bottom longerons
36. Top longerons
37. Central keel member
38. Stressed access panels along decking
39. Double-shock half centre-body
40. Boundary-layer bleed on JP
41. Space for boundary-layer inboard of intake
42. Precision-cast intake lip
43. Drape-type fuel cell
44. Stressed floor to all-fuselage tank bay
45. Pre-closing main-undercarriage doors
46. Liquid Spring unit
47. Door linkage
48. Main retraction jacks
49. Wheel-pivoting linkage
50. Wing carry-through frames
51. Wing pick-up points
52. Machined leading edge (R = 0.016 in)
53. Machined trailing edge
54. Wing root forged brackets
55. Continuous machined skin, root to tip
56. Hinged leading edge
57. Plain flap with blowing
58. Bleed air duct for flap-blowing
59. Leading-edge actuators
60. Flap actuator
61. Grouped aileron actuators (10)
Lockheed F.104A Starfighter
One General Electric J79-GE-3 turbojet with afterburner. Basic data:
Span, 21 ft 11 in; length, 54 ft 9 in; height, 13 ft 6 in; tailplane span, 11 ft 11 in;
Wheelbase, 15 ft 1 in; track, 8 ft 9 in; gross weight, approximately 15,000 lb
bare or 20,000 lb with maximum external stores; maximum speed,
about 1,500 m.p.h. (Mach 2.27); ceiling, over 90,000 ft; extreme range,
over 1,200 miles; landing distance over 50 ft, approximately 5,500 ft.

42 Stores pylon
43 Tip tank (200 U.S. gal)
44 GAR-8 (Sidewinder) air-to-air missile
45 Infra-red seeker head
46 Control servo section
47 Norris-Thermador or Hunter Douglas motor tube
48 Tracking flares
49 Pod containing T.171-E3 gun
50 Linkless ammunition feed
51 Testi, holding 720 rounds
52 Generator access panel
53 Generators (Red Bank division of Bendix)
54 Generator cooling-air feed
55 Chemically milled ducts (see “Aircraft Production,” April 1958)
56 Inner wall of starboard duct
57 Low-speed auxiliary intake doors
58 Hamilton Standard pneumatic starter (60 h.p.)
59 Variable-stator actuator
60 Hydraulic group on engine-bay door
61 Filters
62 Accumulators
63 Charging points
64 Forward portion of ventral fin
65 Air brake ram
66 Fuselage break-joints
67 Attachment-bolt access flaps
68 Engine mounting
69 Afterburner fuel gallery
70 Navigation light
71 Braking parachute door
72 Afterburner
73 Hydraulic nozzle actuators
74 Ejector air duct
75 Tailplane actuator group
76 Tailplane horn
77 Single skin, tip to tip
78 Autostabilizer tab
79 Air-conditioning bay
The very neat main undercarriage (left) utilizes Liquid Spring shock struts of the type pioneered by Dowty Equipment, Ltd.; the units are produced by the Cleveland Pneumatic Tool Co. On the right is a close-up of the port intake, showing the centre body and bleed ducts.

F-104...

the 104 is of necessity associated with a sophisticated intake and exhaust system which enables its full potentialities to be realized at such speeds. The intakes, one of which is depicted in a photograph (above, right) comprise lateral scoops provided with a central shock-forming ramp and two boundary-layer bleed ducts. Pressure recovery is claimed to be almost equivalent to the ideal attainable with an infinity of weak shocks. The ducts are formed from thick light-alloy slabs which are chemically milled to an integrally stiffened form and then stress-relieved by stretching.

Equal importance attaches to the propelling nozzle. In view of the fact that flight Mach number, mass flow, ambient pressure, density and temperature and degree of afterburning can all vary over an exceptional range, the nozzle is of an advanced design with multiple segments giving considerable area variation. These segments are operated by four Aeroproducts high-temperature hydraulic actuators. They are associated with an aerodynamic means for varying nozzle profile, effected by a secondary flow between the jet-pipe and the nozzle segments and a further flow between the nozzle segments and the structure of the rear fuselage.

Fuel is housed in almost every part of the fuselage aft of the main undercarriage or powerplant. Much the largest single cell is a drapetype tank made by Firestone in two-ply nylon impregnated with Buna-N rubber, which is shaped to occupy the spaces between the fuselage frames and thus have the maximum possible capacity. Tanks can be carried under the wings and on the wing tips, two on the wing tips, two on the underwing pylons and one on the centreline ahead of the main-wheel doors. At least one, and probably three, of these locations can accept tactical nuclear weapons, although no 104 has yet been reported to be equipped for automatic toss-bombing.

Assembly of the production 104 was initially assigned solely to the main plant of the Lockheed California Division at Burbank; and, following a practice common among major U.S.A.F. aircraft programmes, manufacture of 40 per cent of the airframe was allocated to a number of sub-contractors. Chief of these are Beech (Wichita), rear fuselage; Goodyear (Litchfield Park), nose; Rheem (Downey), complete tail unit; and Temco (Dallas), port and starboard wings. Lockheed manufacture the mid and forward fuselage sections at both Burbank and their new facility at Palmdale, and the latter plant is now handling all the assembly and flight testing.

It is worth noting that each portion is delivered to Palmdale complete and functionally tested, so that assembly involves little more than making the mechanical connections and coupling up the pipes and cables.

Bulk production began late in 1956. Originally many hundreds of F-104A single-seat fighters were ordered for Tactical Air Command, and output was planned accordingly. But at the end of last year the reduction in the overall size of the U.S.A.F. strength (composed of F-104A squadrons) was felt most keenly by T.A.C., whose air-superiority strength (composed of F-104A squadrons) was cut to what was probably three, of these locations can accept tactical nuclear weapons, although no 104 has yet been reported to be equipped for automatic toss-bombing.

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F-104...

cryptically described as “not very many wings.” As a result the total U.S.A.F. order was pruned to the relatively trivial total of 294 aircraft, and the majority of these have now been built. The result is that big surplus productive capacity exists, and Lockheed are in the fortunate position of being able to offer the aircraft at a very competitive price, all tooling costs having been written off on the existing orders. The mean price per aircraft paid by the U.S.A.F. is reported to be $1,112,000; but the 104 is stated to be available, almost “off the shelf,” at $678,000. This is the figure alleged to have been quoted to the West German government, and it is one which no other manufacturer of a similar product could hope to match.

In the development of the F-104 Lockheed, G.E. and the U.S.A.F. had to face and overcome many very severe problems. Their solution took longer than had been hoped, and squadrons of 104As were not formed until this year. The first deliverables were made to the 83rd Fighter/Interceptor Wing, based at Hamilton A.F.B., near San Francisco, late in February. It is appropriate to list some of the major development programmes which were completed before this release to the user could take place.

Lockheed’s original contract, for two XF-104s, was placed in March 1953. The first of these flew on February 7, 1954. From the XF-104 was evolved the F-104A, the chief differences being an increase in fuselage length to accommodate more fuel, a change in engine from the Wright J65 (Sapphire) to the J79, and minor alterations including a redesigned rear fuselage, a nose undercarriage arrangement to retracted forwards (XF-104 hinged to the rear) and supersonic intakes. The first F-104A flew on February 17, 1956.

One of the most fundamental and protracted programmes was that which cured the super-stalled pitch-up. This cure, already described, was completed by April last year. Extensive flying at the boundaries of the 104’s performance showed that no part of the load-carrying structure could reach a temperature above 200 deg F solely as a result of kinetic heating, and that the 0.016in-radius leading edges of the wing and tail did not erode drastically even in heavy rain or hail. For a considerable period the tip tanks tended to fly in and hit the fuselage after jettisoning, and much work was also necessary to prove the aircraft for gun-firing. GAR-8 firing and stores-dropping. Last winter a machine flying from Eglin A.F.B. showed its range by flying to a target more than 600 miles distant, dropping a simulated nuclear store at maximum speed, flying back and landing with more than 500 lb of fuel remaining.

Squadron pilots seem to have found little difficulty in converting to the type. No simulator is needed, neither does any F-104 squadron yet have the services of a two-seat F-104B. The latter, which is in full production alongside the A model, is fully equipped for operational missions and differs chiefly from the single-seater in having a cockpit which extends back into bays formerly occupied by fuel. Like all recent fighters the 104 is intended for all-weather operation. The ASC-14 radar fire-control system, produced jointly by G.E. (LMIEB), Aerojet-General and R.C.A., is packaged into nest sectors which plug-in around the circular space, some 30in in diameter, in the extreme nose of the aircraft. Pilots have found that, in practice, intensive lock-on training is required if targets are to be held, but their task is eased by the fact that the 104 is an outstandingly good gun-platform.

Most of the really dangerous development flying, in which several aircraft were lost, stemmed from difficulties with the powerplant. This in no way reflects upon G.E., since the J79 was even less of a known quantity than the aircraft when F-104A flying started. It is, however, singularly unfortunate that a major engine snag should have been suffered just after the release of the aircraft to the Air Force. Early in April the U.S.A.F. grounded all 104s fitted with the J79-GE-3A, except for machines engaged in current engine development. Notwithstanding the fact that the J79 as a type had then run some 44,000 hr, it was found that “pure engine trouble” (we quote the U.S.A.F.) was the cause of a series of accidents, in one of which the commander of the 83rd F/I squadron was killed. Roughness, backfiring and flameout in the afterburner was vouchsafed as a particular headache.

Nevertheless, it is fair to regard the basic F-104A as a fully proven weapon system. It is now in service with a number of F/I squadrons, together with all its specially designed support equipment (which, for the benefit of British readers, is regarded as the non-flying portion of the weapon system). Every conceivable type of operational problem has been evaluated and, where possible, simulated; and the proving has extended to such simple, but cumulatively important, items as the number of steps the ground-crew chief needs while walking from the starboard intake to remove the cover over the pitot tube in the nose.

Future developments concern such programmes as zero-length launching with rocket-boost, the dropping of real nuclear stores by various delivery methods, the firing of MB-1s, and the introduction of F-104s fitted with the more powerful GE-7 version of the J79 which has a turbine of 2in greater diameter. There may yet be a pilotless version—a sort of thousand-mile Bomarc—but no requirement for such a device has yet been stated by the U.S.A.F.

The photograph below was taken on May 16 at Edwards A.F.B., when Capt. Walter W. Irwin took off on the flight which promises to bring him the world record for absolute speed. His average speed for the two runs was 1,404.19 m.p.h. The runs were made at 40,000ft in an a.s.f. of —60 deg. C. Even this temperature was too warm, he said, and on other occasions he has exceeded 1,500 m.p.h.