Information regarding the Lockheed F-104 Starfighter

F-104 LN-3

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1. LN-3 (INTERTIAL NAVIGATION SYSTEM)

1.1 Why Inertial navigation?

An inertial navigator is a system, which continually determines the position of a vehicle from measurements made entirely within the vehicle using sensitive instruments. These instruments are accelerometers, which detect and measure vehicle accelerations and gyroscopes, which act to hold the accelerometers in proper orientation. Although complex electronic circuits are required to operate the accelerometers and gyroscopes, the inherent simplicity of the inertial navigator gives it many advantages over the earlier navigation systems.

1.2 Advantages of Inertial Navigation

The principal advantages of inertial navigation equipment are the ability to measure ground speed in the presence of wind, and the complete independence of operating environments. The fact that it does not radiate, is impervious to countermeasures, and not dependent on ground transmitters, has spurred the development of inertial guidance over the past several years. Development has reached a level where, in size, weight, and performance, the inertial system is equal to or better than other automatic navigation methods. Independent of its environment, the inertial system provides velocity information accurately and instantaneously for all manoeuvres. An inertial guidance system also provides an accurate attitude and heading reference. If an inertial system is used other gyros become unnecessary, except for back-up purposes, and other aircraft equipment can make use of the accurate attitude and heading reference information to increase the overall capabilities of the aircraft.

1.3 The accelerometer

The basic measuring instrument of an inertial navigation system is the accelerometer. It is an instrument, which measures the acceleration of the vehicle, which carries it. It consists of a pendulous mass, which is free to rotate about a pivot axis in the instrument. It has an electrical pickoff, which converts the rotation of the test mass about the pivot axis to an output signal. An acceleration of the device to the right causes the pendulum to swing to the left thereby providing an electrical pickoff signal, which causes a torquer to restrain the pendulum. To obtain the correct vehicle acceleration in the horizontal plane, it is necessary to hold the accelerometer level, to exclude the force of gravity.

1.4 The basic inertial navigator

Assume the accelerometer is mounted in a vehicle in such a way that it is always held level. Then the accelerometer would measure the true acceleration of the vehicle in a horizontal direction, along the axis of the accelerometer. By mounting another level accelerometer perpendicular to the first one, the total true acceleration of the vehicle in a horizontal plane would be determined at all the times. In order to convert the measured acceleration to vehicle position information, it is necessary to process the acceleration signals to produce velocity information, and then to process the velocity information to obtain distance travelled. The device, which converts acceleration to velocity and velocity to distance, is called an integrator. If we can provide a means for always pointing one of the accelerometers toward the North, the other one will always point to the East, and by connecting the accelerometers together with integrators, we can determine distance travelled in the North-South and East-West directions. The importance of maintaining the proper accelerometer pointed North and of maintaining both accelerometers level with respect to the surface of the earth is apparent. If the accelerometers were to tilt off level, components of the gravity force would be measured and navigation errors would result. This leads to the need for the next basic part of the inertial navigation system-the gimballed stable element.

1.5 Gyroscope and gimbal system*

The proper orientation of the accelerometers is maintained by mounting them on a platform together with gyroscopes, which are used as sensing elements to control the platform orientation.
A platform, which is controlled by gyros in this way, is referred to as a stable element. The platform is mounted in gimbals, which isolate the platform from angular motions of the aircraft. The stable element is made up of two identical floated, two-degree-of-freedom gyroscopes, mounted one on top of the other in a dumb-bell configuration with their spin axis horizontal and at right angles to each other. Like the familiar child’s toy, the wheels in these gyroscopes, which spin at high speed, resist any effort to change their orientation; that is, once up to speed, the wheels will tend to remain in their original position. The simple navigator, which we have described up to this point, is capable of measuring vehicle displacement on a flat non-moving earth. To describe additional elements will go to far. Rough azimuth alignment of the stable element is accomplished, by using the magnetic compass (flux valve) in the aircraft as a reference, and driving the stable element to north as indicated by the flux valve. However, the azimuth accuracy obtained in this way is not sufficient for precise inertial navigation, so a self-azimuth-alignment by gyro compassing is utilized to complete the alignment process.

1.6 F-104 & LN-3

Litton makes the Inertial Navigator system, named LN-3, chosen for the F-104G. It is a lightweight system, which uses a P-200 inertial platform. The inertial navigator system serves the F-104 in three capacities: it is the vertical reference for attitude information; it is the directional reference for heading information; and it determines aircraft position for computation of bearing, and distance to destination. In conjunction with the PHI (Position and Homing Indicator) system, the inertial navigator computes bearing and distance to any one of twelve pre-selected en route checkpoints or destinations. The inertial navigator is a completely self-contained system which functions without receiving or emitting any electro-magnetic signals that could be detected or jammed by any enemy.

The heart of the inertial navigator is the platform which consists of a four-gimbal, three-axis assembly with the innermost gimbal, or stable element, mounting two, 2-degree-of-freedom gyros, and three mutually perpendicular accelerometers. The platform maintains its vertical axis aligned with the centre of the earth and its north-south axis aligned with true north regardless of aircraft geographic position or attitude. Aircraft geographic position is continuously computed on the basis of signals from the accelerometers. These accelerometers sense aircraft acceleration along the directionally aligned gyro axis, and the computer integrates these acceleration signals to determine instantaneously the speed and distance travelled. In addition to the platform and computer, there is an inertial navigator adapter which serves to resolve various signals supplied to and from the platform. Two control panels for the system are installed in the cockpit. The inertial navigator supplies position, heading, bearing and/or attitude signals to the PHI, attitude indicator, and fire control systems. For the inertial system to perform as a precise navigation system, it is necessary for the inertial platform to be precisely aligned with the true north. A precise alignment can only be made while the aircraft is on the ground. It is also necessary for the flotation fluid in the gyros and other elements of the platform to be stabilized at the proper temperature. Thermostatically controlled heating elements are installed in the platform assembly to control temperature. Appropriate indicator lights are installed in the cockpit to show the pilot when the system has reached operating temperature, and when it is properly aligned. Depending on the temperature of the platform assembly when the system is energized, it may take from 10 to 30 minutes to bring the system up to proper temperature and fine alignments. However, this preparation time is required only if the system is to be operated as a precision navigation system. The time span can be reduced if a slightly degraded navigational accuracy is allowable, or the ground warm-up and fine alignment can be omitted entirely, and the system will function as an attitude reference only. The inertial platform can supply all necessary attitude information in less than three minutes after the system is energized. This is the mode of operation used for alert missions of relatively short radius and duration. Since these missions are usually directed by ground control, precise inertial navigation is not required. The dead reckoning*, TACAN (Tactical Air Navigation), and compass systems provide adequate navigation information, and the inertial system is used to supply attitude signals to the attitude indicator, autopilot and fire control systems.
Pilots in whom aircraft the LN-3 was installed had their own “LN-3 Pilots Handbook” and ”LN-3 Data book “. The data book holds tables of coordinates. The LN-3 system was replaced in the CF-104 by a better system named LW-33. I discussed the LN-3 system with the engineers of the repair shop of the Dutch Air Force. They never had any problems with this system. As the only Starfighter user, they repaired and modified the LN-3 systems with their own engineers and under their own control, also partly for the German Air Force. They developed their own equipment and tools, for their well known: “Quick Service System”.

1.7 PHI (Position and Homing Indicator system)

The PHI system consists of a navigation indicator, a computer, and a control panel, which includes a destination selector. The indicator displays heading, bearing, and distance information. The indicator also includes a navigation information source, or mode selector switch that allows the pilot to select inertial, dead reckoning, or TACAN information for display. The station selector is a rotary switch that can be-preset with geographic position coordinates of up to twelve en route check points, destinations, targets, alternate bases, etc. The coordinates of the selected station are inputs to the PHI system computer. The computer continuously subtracts airplane position coordinates from station coordinates, and thereby computes distance and bearing to the station. This computed distance and bearing information is displayed on the indicator when the inertial or dead reckoning navigation modes are selected. In the inertial navigation mode, airplane position coordinates are derived from the inertial system. In the dead reckoning mode, airplane position is computed on the basis of airplane speed, heading and wind information. The PHI system computer performs dead reckoning computations. It is supplied with speed information from the air data computer; heading information from the inertial navigator or the C-2G compass, plus, wind velocity and direction information, which is put in by the pilot. The controls for making wind data input are on the PHI system control panel. The dead reckoning mode of the PHI system is secondary as a self-contained navigation system, because it is dependent on wind data input from the pilot, and because it cannot navigate as accurately as the inertial system.

*Dead reckoning: The procedure or method of estimating an aircraft position in the air at any time by a calculation involving all or part of the following data: earlier known position, elapsed time, speed, heading, and wind velocity.
* Gimbal: A mechanical frame containing two mutually perpendicular intersecting axes allowing free movement about the plane of each axis.