AEDC-TMR-84-P23

Effects of Inlet Spillage on Store Carriage Loads and Launch Trajectories

Russell B. Sorrells and Lt. Matthew C. Towne
Arnold Engineering Development Center
and
Charles F. Anderson and Ronald H. Tolbert
Calspan Field Services, Inc.

January 1985

Final Report for Period 1 October through 31 December 1983

Approved for public release; distribution unlimited.

ARNOLD ENGINEERING DEVELOPMENT CENTER
ARNOLD AIR FORCE STATION, TENNESSEE
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **JAN 1985**	2. REPORT TYPE	3. DATES COVERED **01-10-1983 to 31-12-1983**

4. TITLE AND SUBTITLE **Effects Of Inlet Spillage On Store Carriage Loads And Launch Trajectories**	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Arnold Engineering Development Center,Arnold Air Force Station,TN,37389**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT
see report

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**6**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

APPROVAL STATEMENT

This report has been reviewed and approved.

ALEXANDER F. MONEY
Aeronautical Systems Branch
Directorate of Aersp Flt Dyn Test
Deputy for Operations

Approved for publication:

FOR THE COMMANDER

ELTON R. THOMPSON
Actg Dep Dir, Aerospace
 Flight Dynamics Test
Deputy for Operations

EFFECTS OF INLET SPILLAGE ON STORE CARRIAGE LOADS AND LAUNCH TRAJECTORIES*

Russell B. Sorrells and Lt Matthew C. Towne
Arnold Engineering Development Center
Arnold Air Force Station, Tennessee 37389

Charles F. Anderson and Ronald H. Tolbert
Calspan Field Services, Inc., AEDC Division
Arnold Air Force Station, Tennessee 37389

Abstract

Aircraft/store compatibility wind tunnel tests have been traditionally conducted without regard for the particular throttle-dependent inlet spillage condition which is simulated in the aircraft model. Tests were conducted in the AEDC 4-ft transonic wind tunnel [Aerodynamic Wind Tunnel (4T)] on a twin-engined, horizontal-ramped inlet fighter aircraft configured with air-to-air missiles and with provisions for simulating both maximum and cruise inlet spillage. The results indicate that for the missile carried nearest to the inlet the carriage loads were as high as 100% larger for the maximum spillage condition than for the cruise spillage condition. Jettison trajectories calculated for this missile indicate that the ejection forces dominate the early portion of the trajectory, and no significant difference was seen between maximum and cruise spillage conditions.

1.0 Introduction

It has been frequently assumed that the inlet spillage condition of the aircraft has little or no effect on store carriage loads or on launch trajectories. Consequently, aircraft/store compatibility wind tunnel tests have been traditionally conducted without regard for the particular throttle-dependent inlet spillage condition which is simulated in the aircraft model. Since the cruise spillage condition is of primary interest for most aircraft aerodynamic performance wind tunnel tests, the typical wind tunnel model is designed to simulate cruise inlet spillage only. This simulation is typically accomplished by a combination of inlet ramp position (if the aircraft has variable-geometry ramps) and nozzle plug size. This combination of inlet ramp position and nozzle blockage is intended to provide the correctly scaled mass flow rate through the inlet and internal ducts of the model which simulates the captured inlet mass flow on the full-scale aircraft for the cruise throttle position. The correctly simulated internal mass flow rate will in turn ensure the proper external flow in the vicinity of the inlet and more importantly the proper aerodynamic flow on stores carried in the vicinity of the inlet and on stores launched through the flow field in the vicinity of the inlet. The question which has needed addressing in many wind tunnel tests is as follows: When the engine is throttled back, is the external flow significantly altered so that store carriage loads and launch trajectories are changed? This question is significant because the primary objective of many aircraft/store compatibility tests is to determine which point in the flight envelope is the critical design point. If the worst case is not identified during the tests, the design safety margin will not be adequate.

The recent acquisition of a new 0.05-scale model of a twin-engined, horizontally ramped inlet fighter aircraft provided the opportunity to answer this question by specifying that the model would simulate both cruise inlet conditions and the maximum anticipated inlet spillage. Consequently, the aircraft manufacturer who designed and built the model sized the nozzle exit plugs so that maximum as well as cruise inlet spillage could be simulated.

Five-component carriage loads data have been acquired in the AEDC 4-ft transonic wind tunnel at Mach numbers from 0.8 to 2.0 and angles of attack from -4 to 20 deg for a twin-engined, horizontal-ramped inlet fighter aircraft configured with air-to-air missiles. Five-component launch transient data were taken at Mach numbers 0.95 and 1.2 and angles of attack of -1 and 20 deg.

2.0 Apparatus

2.1 Test Facility

Tunnel 4T is a closed-loop, continuous-flow, variable-density tunnel in which the Mach number can be varied from 0.1 to 1.3 and can be set at discrete Mach numbers of 1.6 and 1.96 by placing nozzle inserts over the permanent sonic nozzle. At all Mach numbers, the stagnation pressure can be varied from 300 to 3400 psfa. The test section is 4 ft square and 12.5 ft long with perforated, variable-porosity (0.5- to 10-percent open) walls. It is completely enclosed in a plenum chamber from which the air can be evacuated, allowing part of the tunnel airflow to be removed through the perforated walls of the test section (Fig. 1). A complete description of the test facility can be found in the Test Facilities Handbook.[1]

2.2 Model Support

For the launch transient phase of the test, two separate and independent support systems were used to position the aircraft and missile models. The aircraft model was inverted in the test section and supported by an offset sting attached to the boom of the main pitch sector, which has a pitch angle capability of -8 to 27 deg with respect to the tunnel centerline and a roll capability of -180

---

*The research reported herein was performed by the Arnold Engineering Development Center (AEDC), Air Force Systems Command (AFSC). Work and analysis for this research were done by personnel of Hq. AEDC and Calspan Field Services, Inc., operating contractor for the AEDC aerospace flight dynamics facilities.

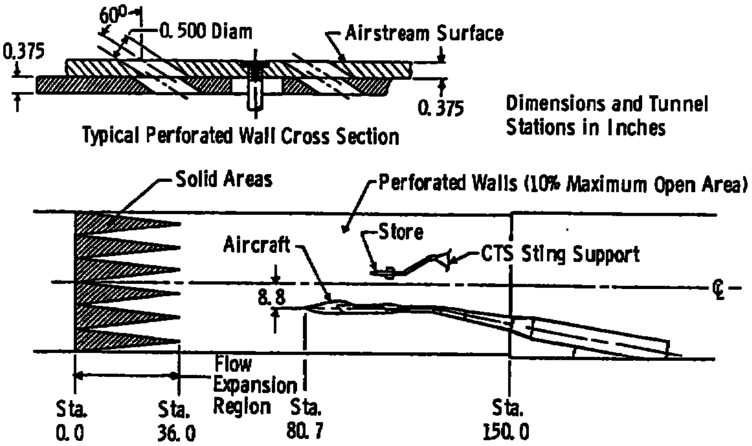


Fig. 1. Schematic of the tunnel test section showing model location.

to 180 deg about the sting centerline. The missile model was supported by a rolling sting assembly mounted to the captive trajectory support (CTS) which extends down from the tunnel diffuser top wall and provides store movement independent of the aircraft model. For the carriage loads phase of the test, the aircraft model was mounted upright in the test section and supported by a straight sting attached to the boom of the main pitch sector.

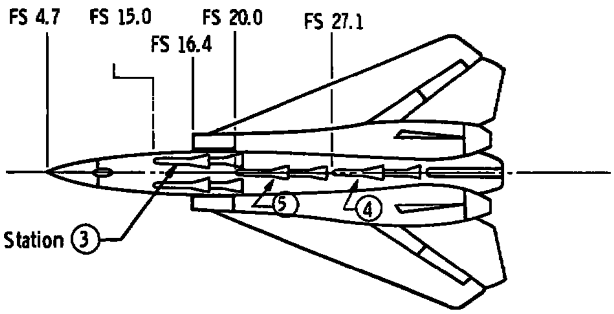
2.3 Test Articles

The test articles were 0.05-scale models of a twin-engined, horizontally ramped inlet fighter aircraft, air-to-air missiles, and associated mounting hardware. A sketch of the aircraft model with the missile carriage positions tested is shown in Fig. 2a. The aircraft model had exchangeable exhaust nozzles (Fig. 2b) to allow testing with inlet flows which would result from two engine power settings: one representing cruise flight and the other representing a high inlet spillage condition within the steady operating range of the inlet. The environmental control system (ECS) inlet (Fig. 2c), located between the inlet splitter plate and the fuselage, was designed to simulate the normal spillage encountered in flight by providing a bluff face with area equal to the spilled air. Fairing blocks for the ECS inlet (Fig. 2c) were provided in order to allow a rough evaluation of the effects of ECS spillage on store loads.

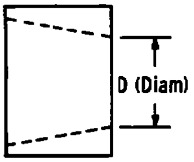
2.4 Instrumentation

For the separation characteristics phase of the test, a five-component, internal, strain-gage balance was used to measure aerodynamic forces and moments acting on the missile model. The aircraft angle of attack was determined using an internal gravimetric angular position indicator.

For the carriage loads phase of the test, five-component store balances were used to measure aerodynamic forces and moments acting on the missile models in the carriage position. The store balances were internal to the missiles mounted on aircraft weapon stations 3, 4, and 5 (see Fig. 2a). A six-component aircraft main balance was used for both the separation and carriage loads test phases.

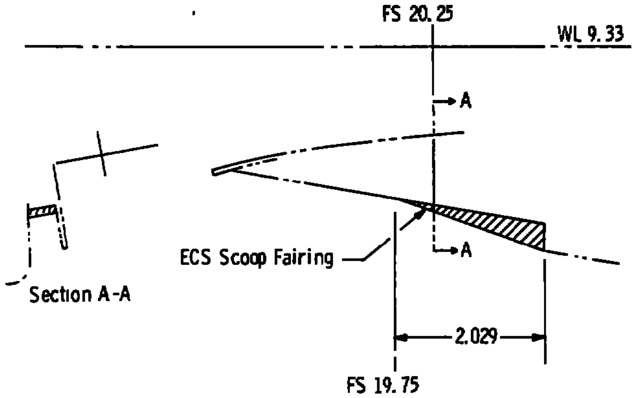


a. Parent aircraft model and store carriage positions.



Exit Area, in.^{2}	D, in.	Power Settings
800	1.596	Cruise, M ≤ 1.2
600	1.382	Cruise, M ≥ 1.6
515	1.280	Max. Spillage, M ≤ 1.6
430	1.170	Max. Spillage, M = 1.96

b. Nozzle exit plugs.



c. Environmental control system scoop fairing.

Fig. 2. Test articles.

3.0 Results and Discussion

3.1 Carriage Loads

The effects of inlet spillage on carriage loads are shown in Fig. 3 for zero angle of attack and sideslip. The data indicate very large effects at station 3, whereas the effects at stations 4 and 5 were less than 10 percent throughout the Mach number range tested. The largest effect was on yawing moment at station 3 and Mach number 1.2 where the maximum spillage values were 100-percent larger than the values at cruise spillage conditions. If the typical design safety margin of 50 percent is used in designing for carriage loads, the ultimate design loads could be exceeded in yawing moment, side force, and pitching moment if the cruise inlet spillage conditions loads were used. The loads for these parameters are 50- to 100-percent larger under maximum spillage conditions than when under cruise spillage conditions.

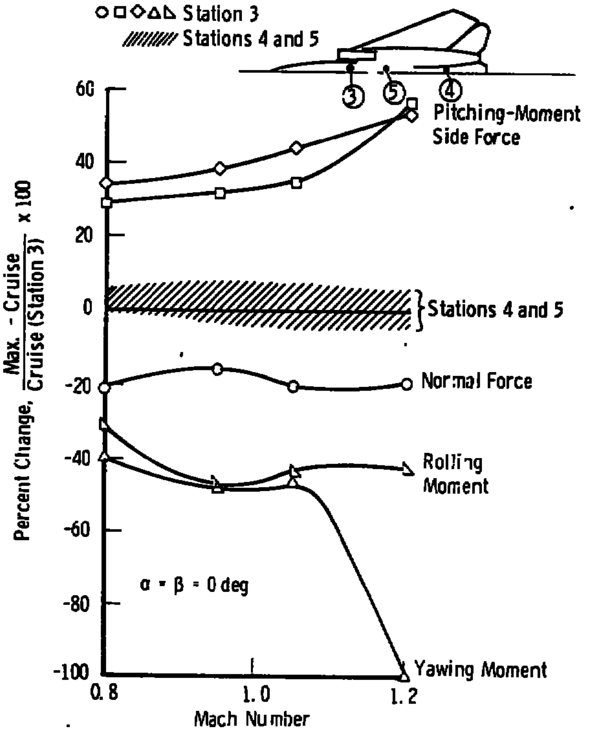


Fig. 3. Effects of inlet spillage on carriage loads.

The signs of the change in normal force and pitching moment on the station 3 missile resulting from increased inlet spillage are what would be expected for a throttled-back condition with a horizontal-ramp inlet since a strong downwash would be expected to emanate from the inlet. The downwash acting on the rear fins of the missile generates a positive pitching moment. The strong effect on side force and yawing moment indicates there is a lateral component in the flow emanating from the inlet with increased spillage.

The effects of 8 degrees angle of attack are shown in Fig. 4. The results for α = 8 deg are typical in indicating that the effects of increased spillage decrease with increasing angle of attack.

The magnitude of the inlet spillage effects suggests that aircraft models with stores carried near the inlet should be designed with a remotely controlled (or at least variable) nozzle plug so that the full range of spillage conditions can be accurately simulated throughout the Mach number range.

The effect on the carriage loads of fairing over the relatively small environmental control system inlet located on the inlet diverter is shown in Fig. 5. The inlet, in its normal configuration, was simulated on the model with a bluff surface since the spillage is typically around 70 percent in normal operation. In order to determine the relative magnitude of the bleed inlet, data were taken with a fairing over the bluff surface. The data indicate that even this relatively small geometry change can have a significant effect (approaching 50 percent for pitching moment) which suggests that small auxiliary inlets located near externally carried stores should be simulated with the correct flow-through mass flow rate when possible.

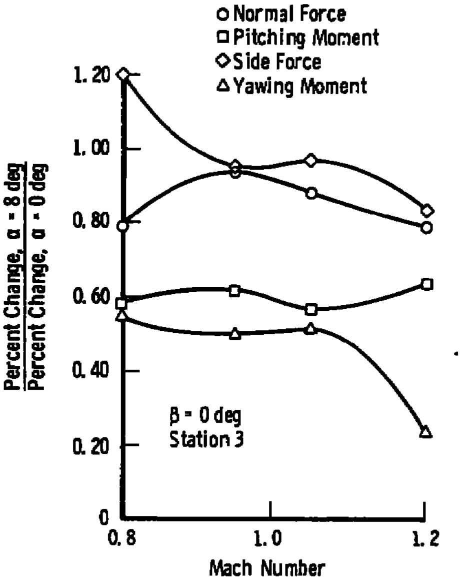


Fig. 4. Effect of angle of attack on the effects of inlet spillage on carriage loads.

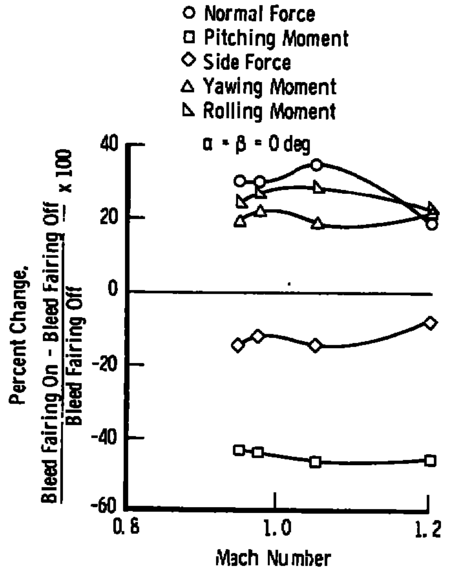


Fig. 5. Effects of bleed fairing on carriage loads.

3.2 Jettison Trajectories

Jettison trajectories for a launch from station 3 were calculated for Mach numbers 0.95 and 1.20 for cruise and maximum spillage (Figs. 6 and 7). The results indicate that although the aerodynamic forces and moments on the jettisoned store at carriage are significantly higher for maximum spillage than for cruise spillage, the ejection forces dominate the early portion of the trajectories. The largest effect, in terms of percentages, is seen in roll angle, but the effect does not appear to be significant.

4.0 Conclusions and Recommendations

The effects of throttle-dependent inlet spillage on store carriage loads in the vicinity of the inlet are large and could result in the ultimate design loads being exceeded if the cruise carriage loads are used in designing for carriage loads.

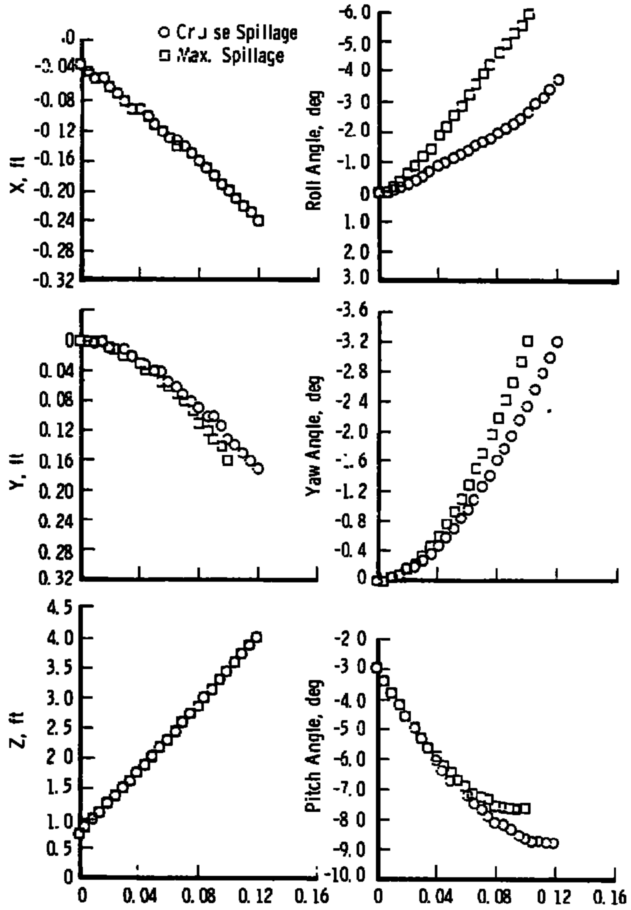


Fig. 6. Jettison trajectories for cruise and maximum inlet spillage at Mach 0.95.

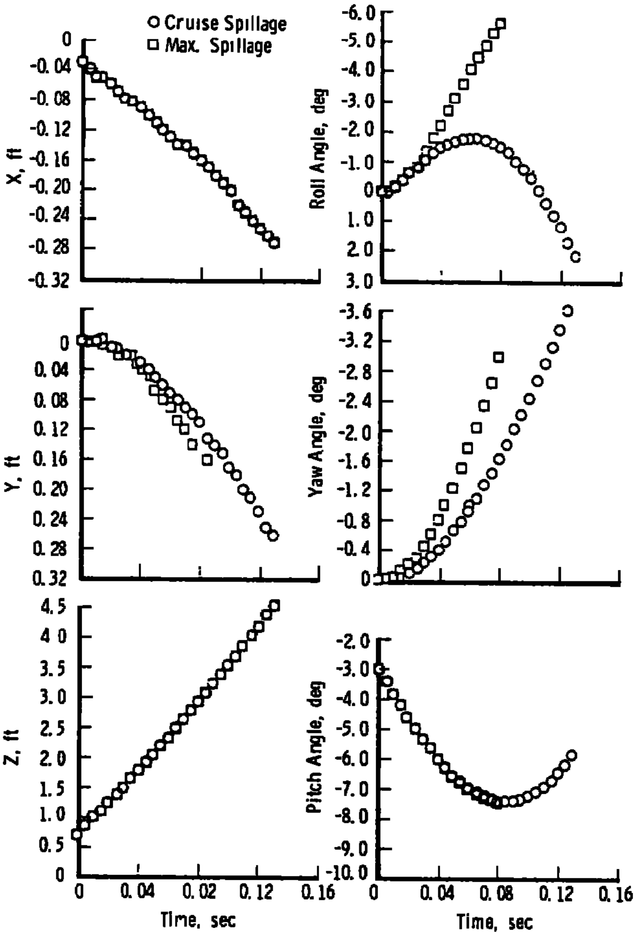


Fig. 7. Jettison trajectories for cruise and maximum inlet spillage at Mach 1.20.

Although the aerodynamic loads are significantly higher for maximum spillage than for cruise spillage, the jettison trajectories did not show a significant difference between maximum and cruise spillage conditions. Carriage loads wind tunnel models which have stores carried near the inlet should be designed with a remotely controlled nozzle plug so that the full range of spillage conditions can be accurately simulated through the Mach number range.

Small auxiliary inlets located near externally carried stores should also be designed to provide an accurate simulation of the captured airflow.

Reference

[1] Test Facilities Handbook, Arnold Engineering Development Center, Arnold Air Force Station, TN (Eleventh Edition), 1981.