FOREWORD

This report presents the results of one segment of an experimental program for the investigation of hypersonic flow separation and control characteristics being conducted by the Research Department of Grumman Aircraft Engineering Corporation, Bethpage, N. Y. Mr. Donald E. Hoak of the Flight Dynamics Laboratory, Research and Technology Division, located at Wright-Patterson Air Force Base, Ohio, is the Air Force Project Engineer for the program, which is being supported primarily under Contract AF 33(616)-8130, Air Force Task 821902.

The experimental data to be obtained, pressure distributions, heat transfer, and six component aerodynamic force data, are extensive and must be presented in a series of reports, of which this is one. These data reports are presented without analysis for the purpose of disseminating experimental information as rapidly as possible. Analyses of the data will be presented in the final report for the subject contract.

The author wishes to express his appreciation to the staff of the von Karman Facility, ARO Inc., for their helpfulness in conducting the tests and particularly to Messrs. Burchfield and Deitering for providing the machine plotted graphs of the experimental data included in this report. The tabulated data, not included herein, are available to qualified Air Force requestors as an appendix to this report. The appendix can be obtained on loan from the Flight Dynamics Laboratory, Research and Technology Division, Air Force Systems Command, Wright-Patterson Air Force Base, Ohio.
ABSTRACT

Pressure data were obtained at Mach 5 for a wired re-entry configuration having aerodynamic controls. The basic model consisted of a clipped delta wing with an overslung cone-cylinder body. The main controls tested were partial span trailing edge flaps. Data were also obtained on the effect of tip fins, hemisphere-cylinder body and a trailing edge spoiler. The data were obtained over an angle of attack range of -50° to +50°. Due to load limitations on the controls the unit test section Reynolds number varied from 3.3 x 10^6 at low angle of attack to 2.3 x 10^6 at high angle of attack.

This report has been reviewed and is approved.

C. L. Bejan

W. A. Sloan, Jr.
Colonel USAF
Chief, Flight Control Division
AF Flight Dynamics Laboratory
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10  \[ \theta = 90^\circ \]

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- b) \( C_p \) vs. \( X' \) \( \theta = \psi = -20 \) lower surface  
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11  \[ \theta = 440^\circ \]

- a) \( C_p \) vs. \( X' \) \( \theta = \psi = 0 \) lower surface  
- b) \( C_p \) vs. \( X' \) \( \theta = \psi = 0 \) upper surface  
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<td>e) $C_p$ vs. $x'$ $b_2 = b_3 = -30$</td>
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Configuration 1 $w = -50$

|               | a) $C_p$ vs. $x'$ $b_2 = b_3 = -30$ | lower surface |        |
|               | b) $C_p$ vs. $x'$ $b_2 = b_3 = 00$  | upper surface | 213    |
|               | c) $C_p$ vs. $y'$ $b_2 = b_3 = -30$ | lower surface |        |
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|               | f) $C_p$ vs. $x'$ $b_2 = b_3 = 00$  | lower surface | 215    |
|               | g) $C_p$ vs. $y'$ $b_2 = b_3 = -30$ | upper surface | 216    |
|               | h) $C_p$ vs. $x'$ $b_2 = b_3 = 00$  | lower surface |        |
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|               | m) $C_p$ vs. $y'$ $b_2 = b_3 = -30$ | lower surface |        |
|               | n) $C_p$ vs. $x'$ $b_2 = b_3 = 00$  | upper surface | 220    |

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|               | e) $C_p$ vs. $y'$ $b_2 = b_3 = 00$  | lower surface |        |
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|               | g) $C_p$ vs. $y'$ $b_2 = b_3 = 00$  | lower surface |        |
|               | h) $C_p$ vs. $x'$ $b_2 = b_3 = -10$ | upper surface | 225    |
|               | i) $C_p$ vs. $y'$ $b_2 = b_3 = 00$  | lower surface |        |
|               | j) $C_p$ vs. $x'$ $b_2 = b_3 = -10$ | lower surface | 226    |
|               | k) $C_p$ vs. $y'$ $b_2 = b_3 = 00$  | upper surface | 227    |
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|               | m) $C_p$ vs. $y'$ $b_2 = b_3 = 00$  | upper surface | 229    |
|               | n) $C_p$ vs. $x'$ $b_2 = b_3 = -10$ | lower surface |        |
|               | o) $C_p$ vs. $y'$ $b_2 = b_3 = 00$  | upper surface | 230    |
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a) $C_p$ vs. $Y'$ $\theta_2 = \theta_3 = 0$ lower surface
b) $C_p$ vs. $Y'$ $\theta_2 = \theta_3 = 0$ upper surface
c) $C_p$ vs. $X'$ $\theta_2 = \theta_3 = 0$ lower surface
d) $C_p$ vs. $X'$ $\theta_2 = \theta_3 = 0$ upper surface

e) $C_p$ vs. $Y'$ $\theta_2 = \theta_3 + 450$ lower surface
f) $C_p$ vs. $X'$ $\theta_2 = \theta_3 + 450$ lower surface

g) $C_p$ vs. $Y'$ $\theta_2 = \theta_3 + 450$ upper surface
h) $C_p$ vs. $X'$ $\theta_2 = \theta_3 + 450$ upper surface

i) $C_p$ vs. $Y'$ $\theta_2 = \theta_3 = 450$ lower surface
j) $C_p$ vs. $Y'$ $\theta_2 = \theta_3 = 450$ upper surface
k) $C_p$ vs. $Y'$ $\theta_2 = \theta_3 = 450$ upper surface

30 Configuration IV $\alpha = 0$

a) $C_p$ vs. $Y'$ $\theta_2 = \theta_3 = -10$ lower surface
b) $C_p$ vs. $Y'$ $\theta_2 = \theta_3 = -10$ upper surface
c) $C_p$ vs. $X'$ $\theta_2 = \theta_3 = -10$ lower surface
d) $C_p$ vs. $X'$ $\theta_2 = \theta_3 = -20$ upper surface
e) $C_p$ vs. $Y'$ $\theta_2 = \theta_3 = -20$ lower surface
f) $C_p$ vs. $X'$ $\theta_2 = \theta_3 = -20$ lower surface

i) $C_p$ vs. $Y'$ $\theta_2 = \theta_3 = -30$ lower surface
j) $C_p$ vs. $Y'$ $\theta_2 = \theta_3 = -30$ lower surface
k) $C_p$ vs. $Y'$ $\theta_2 = \theta_3 = -30$ upper surface
l) $C_p$ vs. $Y'$ $\theta_2 = \theta_3 = -30$ upper surface
m) $C_p$ vs. $Y'$ $\theta_2 = \theta_3 = -30$ upper surface

n) $C_p$ vs. $X'$ $\theta_2 = \theta_3 = -30$ upper surface
o) $C_p$ vs. $X'$ $\theta_2 = \theta_3 = -30$ upper surface
p) $C_p$ vs. $X'$ $\theta_2 = \theta_3 = -30$ upper surface
Configuration IV $\alpha = \pm 10$

a) $C_p$ vs. $Y' \quad b_2 = b_3 = 0$ lower surface
b) $C_p$ vs. $Y' \quad b_2 = b_3 = 0$ upper surface
c) $C_p$ vs. $X' \quad b_2 = b_3 = 0$ lower surface
d) $C_p$ vs. $X' \quad b_2 = b_3 = 0$ upper surface
e) $C_p$ vs. $Y' \quad b_2 = b_3 = 0$ lower surface
f) $C_p$ vs. $X' \quad b_2 = b_3 = 0$ upper surface
g) $C_p$ vs. $Y' \quad b_2 = b_3 = 0$ lower surface
h) $C_p$ vs. $X' \quad b_2 = b_3 = 0$ upper surface
i) $C_p$ vs. $Y' \quad b_2 = b_3 = 0$ lower surface
j) $C_p$ vs. $X' \quad b_2 = b_3 = 0$ upper surface

Configuration IV $\alpha = \pm 10$

a) $C_p$ vs. $Y' \quad b_2 = b_3 = 0$ lower surface
b) $C_p$ vs. $Y' \quad b_2 = b_3 = 0$ upper surface
c) $C_p$ vs. $X' \quad b_2 = b_3 = 0$ lower surface
d) $C_p$ vs. $X' \quad b_2 = b_3 = 0$ upper surface
e) $C_p$ vs. $Y' \quad b_2 = b_3 = 0$ lower surface
f) $C_p$ vs. $X' \quad b_2 = b_3 = 0$ upper surface
g) $C_p$ vs. $Y' \quad b_2 = b_3 = 0$ lower surface
h) $C_p$ vs. $X' \quad b_2 = b_3 = 0$ upper surface
i) $C_p$ vs. $Y' \quad b_2 = b_3 = 0$ lower surface
j) $C_p$ vs. $X' \quad b_2 = b_3 = 0$ upper surface

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<table>
<thead>
<tr>
<th>Configuration IV</th>
<th>( \alpha = 420 )</th>
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<tbody>
<tr>
<td>a) ( c_p ) vs. ( Y' )</td>
<td>( b_2 = b_3 = 0 )</td>
</tr>
<tr>
<td>b) ( c_p ) vs. ( X' )</td>
<td>( b_2 = b_3 = 0 )</td>
</tr>
<tr>
<td>c) ( c_p ) vs. ( Y' )</td>
<td>( b_2 = b_3 = 0 )</td>
</tr>
<tr>
<td>d) ( c_p ) vs. ( X' )</td>
<td>( b_2 = b_3 = 0 )</td>
</tr>
<tr>
<td>e) ( c_p ) vs. ( Y' )</td>
<td>( b_2 = b_3 = -10 )</td>
</tr>
<tr>
<td>f) ( c_p ) vs. ( X' )</td>
<td>( b_2 = b_3 = -10 )</td>
</tr>
<tr>
<td>g) ( c_p ) vs. ( Y' )</td>
<td>( b_2 = b_3 = 10 )</td>
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<tr>
<td>h) ( c_p ) vs. ( X' )</td>
<td>( b_2 = b_3 = 10 )</td>
</tr>
<tr>
<td>i) ( c_p ) vs. ( Y' )</td>
<td>( b_2 = b_3 = -20 )</td>
</tr>
<tr>
<td>j) ( c_p ) vs. ( X' )</td>
<td>( b_2 = b_3 = -20 )</td>
</tr>
<tr>
<td>k) ( c_p ) vs. ( Y' )</td>
<td>( b_2 = b_3 = -20 )</td>
</tr>
<tr>
<td>l) ( c_p ) vs. ( X' )</td>
<td>( b_2 = b_3 = -20 )</td>
</tr>
<tr>
<td>m) ( c_p ) vs. ( Y' )</td>
<td>( b_2 = b_3 = 30 )</td>
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<tr>
<td>n) ( c_p ) vs. ( X' )</td>
<td>( b_2 = b_3 = 30 )</td>
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<tr>
<td>o) ( c_p ) vs. ( Y' )</td>
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<tr>
<td>p) ( c_p ) vs. ( X' )</td>
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35 Configuration IV \( \alpha = +40\)

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<thead>
<tr>
<th>Configuration</th>
<th>Plane</th>
<th>(b_2 \times b_3 = 0)</th>
<th>Surface</th>
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<tbody>
<tr>
<td>a) (C_y \times Y)</td>
<td>lower surface</td>
<td>290</td>
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<tr>
<td>b) (C_y \times X)</td>
<td>lower surface</td>
<td>291</td>
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</tr>
<tr>
<td>c) (C_y \times Y)</td>
<td>upper surface</td>
<td>292</td>
<td></td>
</tr>
<tr>
<td>d) (C_y \times X)</td>
<td>upper surface</td>
<td>293</td>
<td></td>
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<tr>
<td>e) (C_y \times Y)</td>
<td>lower surface</td>
<td>294</td>
<td></td>
</tr>
<tr>
<td>f) (C_y \times X)</td>
<td>lower surface</td>
<td>295</td>
<td></td>
</tr>
<tr>
<td>g) (C_y \times Y)</td>
<td>upper surface</td>
<td>296</td>
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<tr>
<td>h) (C_y \times X)</td>
<td>upper surface</td>
<td>297</td>
<td></td>
</tr>
<tr>
<td>i) (C_y \times Y)</td>
<td>lower surface</td>
<td>298</td>
<td></td>
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<tr>
<td>j) (C_y \times X)</td>
<td>lower surface</td>
<td>299</td>
<td></td>
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<tr>
<td>k) (C_y \times Y)</td>
<td>upper surface</td>
<td>300</td>
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<td>l) (C_y \times X)</td>
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<tr>
<td>m) (C_y \times Y)</td>
<td>upper surface</td>
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</tr>
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36 Configuration IV \( \alpha = +50\)

<table>
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<th>Plane</th>
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<tbody>
<tr>
<td>a) (C_y \times Y)</td>
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<tr>
<td>b) (C_y \times X)</td>
<td>lower surface</td>
<td>304</td>
<td></td>
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<tr>
<td>c) (C_y \times Y)</td>
<td>upper surface</td>
<td>305</td>
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<tr>
<td>d) (C_y \times X)</td>
<td>upper surface</td>
<td>306</td>
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<tr>
<td>e) (C_y \times Y)</td>
<td>lower surface</td>
<td>307</td>
<td></td>
</tr>
<tr>
<td>f) (C_y \times X)</td>
<td>lower surface</td>
<td>308</td>
<td></td>
</tr>
<tr>
<td>g) (C_y \times Y)</td>
<td>upper surface</td>
<td>309</td>
<td></td>
</tr>
<tr>
<td>h) (C_y \times X)</td>
<td>upper surface</td>
<td>310</td>
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</tr>
<tr>
<td>i) (C_y \times Y)</td>
<td>lower surface</td>
<td>311</td>
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<tr>
<td>j) (C_y \times X)</td>
<td>upper surface</td>
<td>312</td>
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</tbody>
</table>
b) $z_2 > z_4$ upper surface 310

j) $z_2 > z_5$ lower surface 313

k) $z_2 > z_6$ upper surface 314

l) $z_2 > z_7$ lower surface 315

a) $z_2 > z_8$ lower surface 316

a) $z_2 > z_9$ upper surface 317

q) $z_2 > z_{10}$ lower surface 318

r) $z_2 > z_{11}$ lower surface 319

t) $z_2 > z_{12}$ upper surface 320

Configuration IV $a = 450$

a) $z_2 > z_3$ lower surface 321

b) $z_2 > z_4$ lower surface 322

c) $z_2 > z_5$ upper surface 323

d) $z_2 > z_6$ lower surface 324

e) $z_2 > z_7$ lower surface 325

Configuration IV $a = 500$

a) $z_2 > z_3$ lower surface 327

b) $z_2 > z_4$ lower surface 328

c) $z_2 > z_5$ upper surface 329

d) $z_2 > z_6$ lower surface 330

e) $z_2 > z_7$ upper surface 331

Configuration IV $a = 550$

a) $z_2 > z_3$ lower surface 332

b) $z_2 > z_4$ lower surface 333

c) $z_2 > z_5$ upper surface 334

d) $z_2 > z_6$ lower surface 335

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### Contrails

<table>
<thead>
<tr>
<th>Configuration IV</th>
<th>α = -10</th>
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<tbody>
<tr>
<td>p) ( C_p \text{ vs. } Y' )</td>
<td>( \beta_2 = \beta_3 = -20 )</td>
</tr>
<tr>
<td>q) ( C_p \text{ vs. } Y' )</td>
<td>( \beta_2 = \beta_3 = -30 )</td>
</tr>
<tr>
<td>r) ( C_p \text{ vs. } X' )</td>
<td>( \beta_2 = \beta_3 = -30 )</td>
</tr>
<tr>
<td>s) ( C_p \text{ vs. } Y' )</td>
<td>( \beta_2 = \beta_3 = -30 )</td>
</tr>
<tr>
<td>t) ( C_p \text{ vs. } X' )</td>
<td>( \beta_2 = \beta_3 = -30 )</td>
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<table>
<thead>
<tr>
<th>Configuration IV</th>
<th>α = -10</th>
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<tbody>
<tr>
<td>a) ( C_p \text{ vs. } Y' )</td>
<td>( \beta_2 = \beta_3 = 0 )</td>
</tr>
<tr>
<td>b) ( C_p \text{ vs. } Y' )</td>
<td>( \beta_2 = \beta_3 = 0 )</td>
</tr>
<tr>
<td>c) ( C_p \text{ vs. } X' )</td>
<td>( \beta_2 = \beta_3 = 0 )</td>
</tr>
<tr>
<td>d) ( C_p \text{ vs. } Y' )</td>
<td>( \beta_2 = \beta_3 = 0 )</td>
</tr>
<tr>
<td>e) ( C_p \text{ vs. } Y' )</td>
<td>( \beta_2 = \beta_3 = 0 )</td>
</tr>
<tr>
<td>f) ( C_p \text{ vs. } Y' )</td>
<td>( \beta_2 = \beta_3 = 0 )</td>
</tr>
<tr>
<td>g) ( C_p \text{ vs. } X' )</td>
<td>( \beta_2 = \beta_3 = 0 )</td>
</tr>
<tr>
<td>h) ( C_p \text{ vs. } Y' )</td>
<td>( \beta_2 = \beta_3 = 0 )</td>
</tr>
<tr>
<td>i) ( C_p \text{ vs. } Y' )</td>
<td>( \beta_2 = \beta_3 = 0 )</td>
</tr>
<tr>
<td>j) ( C_p \text{ vs. } Y' )</td>
<td>( \beta_2 = \beta_3 = 0 )</td>
</tr>
<tr>
<td>k) ( C_p \text{ vs. } Y' )</td>
<td>( \beta_2 = \beta_3 = 0 )</td>
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</table>

<table>
<thead>
<tr>
<th>Configuration IV</th>
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<tbody>
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<td>( \beta_2 = \beta_3 = 10 )</td>
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<tr>
<td>b) ( C_p \text{ vs. } Y' )</td>
<td>( \beta_2 = \beta_3 = 10 )</td>
</tr>
<tr>
<td>c) ( C_p \text{ vs. } X' )</td>
<td>( \beta_2 = \beta_3 = 10 )</td>
</tr>
<tr>
<td>d) ( C_p \text{ vs. } Y' )</td>
<td>( \beta_2 = \beta_3 = 10 )</td>
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<tr>
<td>e) ( C_p \text{ vs. } Y' )</td>
<td>( \beta_2 = \beta_3 = 10 )</td>
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<tr>
<td>f) ( C_p \text{ vs. } Y' )</td>
<td>( \beta_2 = \beta_3 = 10 )</td>
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<table>
<thead>
<tr>
<th>Configuration IV</th>
<th>α = -10</th>
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<tbody>
<tr>
<td>a) ( C_p \text{ vs. } Y' )</td>
<td>( \beta_2 = \beta_3 = -10 )</td>
</tr>
<tr>
<td>b) ( C_p \text{ vs. } Y' )</td>
<td>( \beta_2 = \beta_3 = -10 )</td>
</tr>
<tr>
<td>c) ( C_p \text{ vs. } Y' )</td>
<td>( \beta_2 = \beta_3 = -10 )</td>
</tr>
<tr>
<td>d) ( C_p \text{ vs. } Y' )</td>
<td>( \beta_2 = \beta_3 = -10 )</td>
</tr>
<tr>
<td>e) ( C_p \text{ vs. } Y' )</td>
<td>( \beta_2 = \beta_3 = -10 )</td>
</tr>
<tr>
<td>f) ( C_p \text{ vs. } Y' )</td>
<td>( \beta_2 = \beta_3 = -10 )</td>
</tr>
<tr>
<td>g) ( C_p \text{ vs. } Y' )</td>
<td>( \beta_2 = \beta_3 = -10 )</td>
</tr>
<tr>
<td>h) ( C_p \text{ vs. } Y' )</td>
<td>( \beta_2 = \beta_3 = -10 )</td>
</tr>
<tr>
<td>i) ( C_p \text{ vs. } Y' )</td>
<td>( \beta_2 = \beta_3 = -10 )</td>
</tr>
<tr>
<td>j) ( C_p \text{ vs. } Y' )</td>
<td>( \beta_2 = \beta_3 = -10 )</td>
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<table>
<thead>
<tr>
<th>Configuration</th>
<th>$a = -20$</th>
<th>$b_1 = b_3 = -10$</th>
<th>$b_2 = b_4 = -30$</th>
<th>\textit{upper surface}</th>
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</thead>
<tbody>
<tr>
<td>a) $C_p$ vs. $V'$</td>
<td>$b_2 = b_4 = 0$</td>
<td>lower surface</td>
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<tr>
<td>b) $C_p$ vs. $X'$</td>
<td>$b_2 = b_4 = 0$</td>
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<tr>
<td>c) $C_p$ vs. $Y'$</td>
<td>$b_2 = b_4 = 0$</td>
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<tr>
<td>d) $C_p$ vs. $Z'$</td>
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<tr>
<td>e) $C_p$ vs. $T'$</td>
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<tr>
<td>f) $C_p$ vs. $U'$</td>
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<tr>
<td>g) $C_p$ vs. $W'$</td>
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<td>j) $C_p$ vs. $Z'$</td>
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<td>k) $C_p$ vs. $T'$</td>
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<td>l) $C_p$ vs. $U'$</td>
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<td>n) $C_p$ vs. $X'$</td>
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<td>o) $C_p$ vs. $Y'$</td>
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<td>q) $C_p$ vs. $T'$</td>
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<td>r) $C_p$ vs. $U'$</td>
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<td>s) $C_p$ vs. $W'$</td>
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<td>t) $C_p$ vs. $X'$</td>
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<td>w) $C_p$ vs. $T'$</td>
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<td>y) $C_p$ vs. $W'$</td>
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<td>bb) $C_p$ vs. $Z'$</td>
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<td>cc) $C_p$ vs. $T'$</td>
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<td>dd) $C_p$ vs. $U'$</td>
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<td>ee) $C_p$ vs. $W'$</td>
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<tr>
<td>ff) $C_p$ vs. $X'$</td>
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<td>gg) $C_p$ vs. $Y'$</td>
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<tr>
<td>hh) $C_p$ vs. $Z'$</td>
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<td>ii) $C_p$ vs. $T'$</td>
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<td>jj) $C_p$ vs. $U'$</td>
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<td>kk) $C_p$ vs. $W'$</td>
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<tr>
<td>Configuration IV</td>
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<td>b) $C_p$ vs. $X'$</td>
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<td>c) $C_p$ vs. $Y'$</td>
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<td>d) $C_p$ vs. $X'$</td>
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Configuration IV

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e) $C_p$ vs. $Y$' $\alpha = 0$ lower surface
f) $C_p$ vs. $X$' $\alpha = 0$ lower surface

g) $C_p$ vs. $Y$' $\alpha = 0$ upper surface
h) $C_p$ vs. $X$' $\alpha = 0$ upper surface

Configuration VII

a) $C_p$ vs. $Y$' $\alpha = 0 \text{ Re}_x / \text{ft} \times 10^{-6} = 3.3$ lower surface
b) $C_p$ vs. $X$' $\alpha = 0 \text{ Re}_x / \text{ft} \times 10^{-6} = 3.3$ lower surface
c) $C_p$ vs. $Y$' $\alpha = 0 \text{ Re}_x / \text{ft} \times 10^{-6} = 3.3$ upper surface
d) $C_p$ vs. $X$' $\alpha = 0 \text{ Re}_x / \text{ft} \times 10^{-6} = 3.3$ upper surface
e) $C_p$ vs. $Y$' $\alpha = 10 \text{ Re}_x / \text{ft} \times 10^{-6} = 3.3$ lower surface
f) $C_p$ vs. $X$' $\alpha = 10 \text{ Re}_x / \text{ft} \times 10^{-6} = 3.3$ lower surface
g) $C_p$ vs. $Y$' $\alpha = 10 \text{ Re}_x / \text{ft} \times 10^{-6} = 3.3$ upper surface
h) $C_p$ vs. $X$' $\alpha = 10 \text{ Re}_x / \text{ft} \times 10^{-6} = 3.3$ upper surface

Configuration VIII

a) $C_p$ vs. $Y$' $\alpha = 20 \text{ Re}_x / \text{ft} \times 10^{-6} = 3.3$ lower surface
b) $C_p$ vs. $X$' $\alpha = 20 \text{ Re}_x / \text{ft} \times 10^{-6} = 3.3$ lower surface
c) $C_p$ vs. $Y$' $\alpha = 20 \text{ Re}_x / \text{ft} \times 10^{-6} = 3.3$ upper surface
d) $C_p$ vs. $X$' $\alpha = 20 \text{ Re}_x / \text{ft} \times 10^{-6} = 3.3$ upper surface

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e) $C_p$ vs. $Y'$  \( \alpha = -5 \)  lower surface

f) $C_p$ vs. $X'$  \( \alpha = -5 \)  lower surface

g) $C_p$ vs. $Y'$  \( \alpha = -5 \)  upper surface

h) $C_p$ vs. $X'$  \( \alpha = -10 \)  upper surface

i) $C_p$ vs. $Y'$  \( \alpha = -10 \)  lower surface

j) $C_p$ vs. $X'$  \( \alpha = -10 \)  upper surface

k) $C_p$ vs. $Y'$  \( \alpha = -20 \)  upper surface

l) $C_p$ vs. $X'$  \( \alpha = -20 \)  lower surface

m) $C_p$ vs. $X'$  \( \alpha = -20 \)  lower surface

n) $C_p$ vs. $X'$  \( \alpha = -20 \)  upper surface

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LIST OF SYMBOLS

\( b \)  
Wing semi-span \( \sim \) inches

\( C_p \)  
pressure coefficient \( = \frac{P - P_\infty}{q_\infty} \)

\( c_{root} \)  
virtual root chord of wing \( \sim \) inches (virtual)

\( M_\infty \)  
free stream Mach number

\( P \)  
static pressure measured at pressure tap \( \sim \) psia

\( P_\infty \)  
free stream static pressure \( \sim \) psia

\( q_\infty \)  
free stream dynamic pressure \( = \frac{\gamma}{2} P_\infty M_\infty^2 \) \( \sim \) psia

\( Re_{o/ft} \)  
free stream unit Reynolds number \( = \frac{\rho_\infty V_\infty}{\mu_\infty} \)

\( V_\infty \)  
free stream velocity \( \sim \) ft/sec

\( x \)  
chordwise distance measured from virtual apex of wing \( \sim \) inches

\( X' \)  
non-dimensional chordwise coordinate \( = \frac{x}{c_{root}} \) (measured from virtual apex of wing) (virtual)

\( y \)  
spanwise distance measured from centerplane of model \( \sim \) inches

\( Y' \)  
non-dimensional spanwise coordinate \( = \frac{Y}{b} \) (measured from vertical centerplane of model)

\( \alpha \)  
sage of attack \( \sim \) degrees
\( \gamma \) \hspace{1cm} \text{ratio of specific heats} = 1.4

\( \delta_2, \delta_3 \) \hspace{1cm} \text{flap deflection angles} \sim \text{degrees}
\( \delta_2 \sim \text{left flap}; \ \delta_3 \sim \text{right flap} \)

\( \mu_\infty \) \hspace{1cm} \text{free stream viscosity} \sim \text{slugs ft sec}^{-1}

\( \rho_\infty \) \hspace{1cm} \text{free stream density} \sim \frac{\text{slugs}}{\text{ft}^3}
INTRODUCTION

The Fluid Mechanics Section of the Grumman Research Department is currently engaged in a research program directed at determining flow separation phenomena and the effectiveness of aerodynamic controls on hypersonic flight vehicles. The program consists of theoretical and experimental research on "basic" configurations, flat plates with wedge-shaped flaps and fins, and "typical" hypersonic glide vehicles, a clipped delta wing-body combination, and a pyramidal body. The configurations under investigation in the over-all program are shown in Fig. 1a.

This report presents the results of one segment of the experimental program. It treats a winged hypersonic glider configuration consisting, in basic form, of a clipped delta wing with an overslung cone-cylinder body. This configuration was used for obtaining pressure and heat transfer data on various aerodynamic controls at hypersonic Mach numbers. The pressure data results are presented herein and the heat transfer results will be presented in a subsequent report (Ref. 1). The controls investigated were partial span trailing edge flaps, with deflection ranges of -39° to +39°, a full span plug-type trailing edge spoiler and tip fins. An overslung hemisphere-cylinder body was also tested.

The experimental work was done at the AEDC 50-inch Mach 8 Hypersonic Wind Tunnel during July and August of 1963. Descriptions of these test facilities can be found in Ref. 2. Pressure data were obtained at a unique Reynolds number varying from $3.3 \times 10^6$ to $2.5 \times 10^6$, depending on the angle of attack range, with selected points at a Reynolds number of $1.1 \times 10^6$. The same model was used to obtain heat transfer data in the AEDC 50-inch Hypersonic Tunnel at $M_\infty = 8.0$ and pressure data in the AEDC 43" x 40" Supersonic Tunnel at $M = 5.0$ (Ref. 3). A geometrically similar model, instrumented to obtain force and moment data, was tested in both the 40" and 50" tunnels at an earlier date (Ref. 4). Another geometrically similar model, with limited pressure instrumentation, was tested in the AEDC Hotshot 2 Hypervelocity Tunnel (Ref. 5).

Manuscript released by the author May 1964 for publication as an RTD Technical Documentary Report.
Four test configurations were built up from a basic model that consisted of a clipped delta wing with an overslung body. The clipped delta wing had a spherically blunted apex, cylindrically blunted leading edges and a blunt base. Of the control surfaces to be tested, three partial span trailing edge flaps were built into the wing and attachments provided for mounting a full span spoiler. Only the outboard flaps were used in these tests. The flap-type control surfaces were remotely actuated from outside the tunnel. Three-view drawings of the four test configurations are presented in Fig. 1b through e. The dimensions of the basic configurations are shown in Fig. 1b and are the same for all other configurations. The other configuration drawings show dimensions only for the components added to the basic configuration. A summary of the geometric properties of the various model components is presented in Table 2.

The first major configuration consisted of a clipped delta wing with an overslung body. The body was composed of a half-cylindrical after-section and a half-hemispherical fore-section. A conical fairing, uninstrumented, was attached over the fore-section of the body to provide a body shape that was geometrically similar to that used in the force tests (Ref. 4). The half-conical foresection and half-cylindrical aftersection were joined together at the shoulder by a spherical fairing; this wing-body combination is referred to as Configuration I. The second major configuration was obtained by adding a set of tip fins to Configuration I and is referred to as Configuration IV. The tip fins were clipped deltas in elevation and were attached in such a way as not to alter the aspect ratio of the basic configuration. Configurations I and IV provided the pressure data needed to evaluate the force data previously obtained.

The conical forebody of the overslung body generates a weak shock wave on the upper surface. It was also desired to determine the effects of a strong shock generator on the pressure coefficients. With the conical forebody removed the basic, hemispherical-cylindrical overslung body remaining can be considered as a strong shock generator. It was also desired to compare the flow separation characteristics of the partial span trailing edge flaps with those of a trailing edge control that would be expected to induce strong separation effects. Thus, as for the force tests, it was decided to test a full span spoiler and compare the resulting pressure
distributions to those due to the partial span flaps deflected +20 degrees. The design condition for the full span, plug type, trailing edge spoiler was, therefore, that its height be equal to the vertical displacement of the trailing edge flaps when they are deflected +20 degrees. This spoiler was attached to the lower, flat plate surface at the trailing edge.

It was assumed that the effects of the blunt body and spoiler would be uncoupled because of their locations on opposite surfaces of the wing. Therefore, the hemispherical overslung body and the trailing edge spoiler were tested at the same time and referred to as Configuration VII.* Configuration VIII was obtained by adding the tip fins to Configuration VII.

The sign convention for denoting the angle of attack and the control deflection angle can be obtained from the basic model; namely, a flat plate clipped delta wing with an overslung body. This definition fixes the flat plate surface of the wing as the lower surface. Thus, the angle of attack is positive when the flat plate surface is the windward surface of the model. The control deflection angles are also defined with respect to the lower (flat-plate) surface of the model. If we consider our model at zero angle of attack (flow parallel to the lower flat-plate surface), then positive trailing edge flap deflections are obtained by deflecting the trailing edge down. The outboard partial span trailing edge flaps, designed to operate independently of each other, had a maximum travel angle of ±40 degrees and could be calibrated to yield any deflection angle in this range.

Each flap-type control was driven by a 28 volt dc, gear-reduced, electrical motor through a 1/2 inch-10 acme thread drive screw which was connected to the flap bell cranks by push-pull rods. Control deflection read-outs were obtained through calibrated linear potentiometers. The three motors with their attendant potentiometers and drive screws were located in a water-cooled housing immediately behind the model. The drive screws were connected to the flap bell cranks by push-pull rods that passed through the front of the actuator housing and into the base of the model. This type of actuation system produced a deflection rate of 1 degree/sec. The control surfaces were calibrated cold, that is, when the model was installed in the tunnel, and checked regularly. The calibrating was done with precut templates varying, in 5-degree increments, from 0 degrees to

*In the force tests a full span trailing edge flap and a full span spoiler were tested with the conical overslung body, with and without tip fins, and referred to as Configurations II, III, V, and VI.
40 degrees. The potentiometer outputs were recorded visually from Leeds and Northrup Midget Model D indicators for use in setting flap angles during the test. This calibration was also recorded into the digital computing equipment at AEDC for use of the computer during the print-out procedure. The design provided for the independent operation of each control surface. We were thus capable of testing asymmetric, as well as symmetric, control configurations.

The wing of the model was fabricated of an internal stainless steel frame which served as the basic load supporting structure and instrumented surface panels which served as the data gathering units. The flaps were also fabricated the same way; i.e., an internal frame with attached, instrumented, panels. The flaps were connected to the wing structure by hinges and actuated from the actuator housing by a system of bell cranks and push-pull rods. All internal framework was made of 416 stainless steel and the surface panels were pressure relieved, silver braised honeycomb sections where the face sheets, core and frame were of 321 stainless steel. The body and the conical fairing were fabricated of 321 stainless steel sheet. The fins and spoiler were made of solid 321 stainless steel. The actuator housing which served as the connection between the model and the sting, as well as the housing for the actuation motors, was made of 17-4PH stainless steel.

The model was instrumented with 56 pressure taps distributed on the upper and lower surface of the wing and on the half-hemisphere cylinder body. The location of each pressure tap is listed in Table 3 and shown in Fig. 1f. When the conical forebody fairing was installed, seven pressure taps (178-184) were lost and when the spoiler was installed four pressure taps (28, 38, 48, 88) were lost. Installation of the fins did not block any instrumentation.

DESCRIPTION OF WIND TUNNELS AND EQUIPMENT

This segment of the over-all experimental program described in the Introduction was conducted in the 50 in. Mach 8 Hypersonic Wind Tunnel located at Arnold Engineering Development Center's von Karman Facility. A complete description of the wind tunnels and their associated measuring, recording, and tabulating equipment is given in Ref. 2.
The angle of attack range was obtained by using two different pre-bend angles on the water-cooled split sting that is standard tunnel equipment. The two pre-bend angles used were 12 degrees and 39 degrees and between them provided an angle of attack range of 0 degrees to ±50 degrees. The negative angles of attack were obtained by inverting the model.

TEST CONDITIONS

The test program was conducted at a nominal test section Mach number of 8.0 and test section unit Reynolds numbers ranging from 3.3 x 10⁶ per foot to 1.1 x 10⁶ per foot. Only selected data, to be used for comparative purposes, were obtained at the lowest unit Reynolds number. Most of the program was conducted at unit Reynolds numbers ranging from 3.3 x 10⁵ per foot to 2.5 x 10⁶ per foot. This variation in test section unit Reynolds number was caused by the necessity to reduce the free stream dynamic pressure in order to prevent overloading the control system. Thus the free stream unit Reynolds numbers and dynamic pressures were reduced as the magnitude of the angle of attack increased.

Due to tunnel operating conditions the actual test section Mach number ranged between 8.08 and 8.09. The nominal values of the free stream unit Reynolds number at which data were acquired were 3.3 x 10⁶, 2.9 x 10⁶, 2.5 x 10⁶, and 1.1 x 10⁶. The variation in Reynolds number, due to tunnel operating conditions, was ± 3% maximum with most of the variations being within ± 2% of the nominal values.

The two main configurations (I and IV) were tested most extensively while the tests on the other configurations were restricted and are used only to provide comparison data with the main configurations. Configurations I and IV were tested through an angle of attack range from -50 degrees to +50 degrees, for symmetric, partial span, flap deflections of -39 degrees to +39 degrees. Configurations VII and VIII were tested through an angle of attack range of -20 degrees to 0 degrees and provide information on the effect of a strong shock generator and plug type trailing edge spoiler on the pressure distributions and flow field about the delta wing.

A complete tabulation of the test program showing the angle of attack range, control deflection and flow conditions, is presented in Table 1.
All the pressure data were reduced to standard coefficient form using the equation \( C_p = \frac{P - P_0}{\frac{1}{2} \rho V^2} \). The inaccuracy in the measured pressure data varied from \( \pm 0.003 \text{ psia} \), for pressures below 0.40 psia, to 0.26 psia for pressures above 15 psia. Because of this, pressure coefficient uncertainties varied from 0.004 for \( C_p < 0.3 \) and \( Re_c/ft = 11.1 \text{ million} \) to 0.13 for \( C_p = 2.0 \) and \( Re_c/ft = 3.3 \text{ million} \).

The automatic plotting machines, used in presenting the data herein, introduce additional errors. The discrepancies in the plotted pressure coefficients due to these machine errors should not exceed \( \pm 0.01 \). Nevertheless, there is always the possibility that a point will be completely misplotted. Each graph has been inspected and any questionable points were checked with the tabulated pressure coefficients.

RESULTS AND DISCUSSION

This portion of the over-all test program was designed to provide the pressure data needed to fully exploit the controls information previously obtained (Refs. 1 and 4) on a basic type of hypersonic flight vehicle and to assess the importance of separated flow effects. Data are presented at positive and negative angles of attack for the case of an overslung body mounted on a clipped delta wing.

The model was tested with tip flaps on and off, with partial span trailing edge flaps, with a full span trailing edge spoiler, and with a blunt instrumented body as well as the conical body used in the force tests. The experiments were conducted at a nominal Mach number of 8 and with limited Reynolds number comparisons.

The basic wing-body combination was designed to provide pressure data for configurations having either overslung or underslung bodies. For convenience we have chosen the overslung body configuration as our reference, and we have defined the coordinate system and control deflection angles with reference to this basic configuration. Thus the positive angle of attack regime for the overslung body provides the aerodynamic data for the underslung
body at negative angles of attack. The sign of the flap deflection angles, for the underslung body case, must be reversed in order that both cases be viewed in the same reference system.

The data are presented in the form of pressure coefficients plotted as functions of nondimensionalized chordwise (streamwise), and spanwise, coordinates. The chordwise coordinate is measured from the virtual apex of the model and the spanwise coordinate from the vertical centerplane of the model. The data obtained on the upper and lower surfaces of the test configuration are presented separately for each set. Thus, for each test configuration, all the data are presented in four graphs (two graphs for the chordwise plots and two graphs for the spanwise plots).

The data for Configuration I are presented in Figs. 3 to 28; for Configuration IV in Figs. 29 to 49; for Configuration VII in Fig. 50 and for Configuration VIII in Fig. 51. The complete test program is tabulated in Table I and the specific conditions presented in each figure are noted in the list of illustrations on page VIII.
REFERENCES

1. Meckler, Lawrence, Heat Transfer Measurements at Mach 8 on an Aerodynamically Controllable Winged Re-entry Configuration, to be published.


4. Meckler, Lawrence, Static Aerodynamic Characteristics at Mach 5 and 8 of an Aerodynamically Controllable Winged Re-entry Configuration, FDL-TDR-64-10, to be published.

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<td></td>
<td>-30 (\rightarrow) -50</td>
</tr>
<tr>
<td></td>
<td>-30</td>
<td>-30</td>
<td></td>
<td>-30 (\rightarrow) -50</td>
</tr>
<tr>
<td></td>
<td>-39</td>
<td>-39</td>
<td></td>
<td>-30 (\rightarrow) -50</td>
</tr>
</tbody>
</table>

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<table>
<thead>
<tr>
<th>CONFIGURATION</th>
<th>TRAILING EDGE CONTROL</th>
<th>FOREBODY SHAPE</th>
<th>θ MISES</th>
<th>Re/ft x 10^-6</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>s_2</td>
<td>s_3</td>
<td>OFF</td>
<td>CONICAL</td>
</tr>
<tr>
<td>IV</td>
<td>-10</td>
<td>-10</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>-20</td>
<td>-20</td>
<td></td>
<td>2.875</td>
</tr>
<tr>
<td></td>
<td>-30</td>
<td>-30</td>
<td></td>
<td>2.875</td>
</tr>
<tr>
<td></td>
<td>-39</td>
<td>-39</td>
<td></td>
<td>2.875</td>
</tr>
<tr>
<td>VII</td>
<td>0</td>
<td>0</td>
<td>ON</td>
<td>BLUNT</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VIII</td>
<td>0</td>
<td>0</td>
<td>ON</td>
<td>BLUNT</td>
</tr>
</tbody>
</table>

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### Wing:

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clipped Delta Wing with Blunt Apex, Leading Edges, and Base</td>
<td></td>
</tr>
<tr>
<td>Root Chord</td>
<td>12.290 inches actual</td>
</tr>
<tr>
<td>Tip Chord</td>
<td>12.09 inches virtual</td>
</tr>
<tr>
<td>Span</td>
<td>12.00 inches</td>
</tr>
<tr>
<td>Apex Radius</td>
<td>0.650 inches</td>
</tr>
<tr>
<td>Leading Edge Sweep</td>
<td>60 degrees</td>
</tr>
<tr>
<td>Leading Edge Radius</td>
<td>0.650 inches</td>
</tr>
<tr>
<td>Wing Thickness (Constant)</td>
<td>1.30 inches</td>
</tr>
<tr>
<td>Planform Area</td>
<td>93.3 inches² actual, 107.6 inches² virtual</td>
</tr>
<tr>
<td>Aspect Ratio</td>
<td>1.542</td>
</tr>
<tr>
<td>Taper Octa</td>
<td>0.211</td>
</tr>
<tr>
<td>Thickness Ratio (Root)</td>
<td>0.1052</td>
</tr>
<tr>
<td>Control Area − Partial Span Flaps</td>
<td>12.75 inches²</td>
</tr>
</tbody>
</table>

### Body:

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Half Cone - Cylinder (Base Mounted Flush with Wing Trailing Edge)</td>
<td></td>
</tr>
<tr>
<td>Cone Angle</td>
<td>13 degrees</td>
</tr>
<tr>
<td>Cone Length</td>
<td>5.69 inches</td>
</tr>
<tr>
<td>Cone Radius (Maximum at Tangency Point)</td>
<td>1.269 inches</td>
</tr>
<tr>
<td>Cylinder Length</td>
<td>4.435 inches</td>
</tr>
<tr>
<td>Cylinder Radius</td>
<td>1.30 inches</td>
</tr>
<tr>
<td>Fairing (Cone to Cylinder)</td>
<td></td>
</tr>
<tr>
<td>Length</td>
<td>0.292 inches</td>
</tr>
<tr>
<td>Radius</td>
<td>1.30 inches</td>
</tr>
<tr>
<td>Included Angle</td>
<td>13 degrees</td>
</tr>
<tr>
<td>Total Body Length (Half-Cone Cylinder)</td>
<td>10.20 inches</td>
</tr>
<tr>
<td>Planform Area (Half-Cone Cylinder)</td>
<td>17.81 inches²</td>
</tr>
<tr>
<td>Hemisphere Radius</td>
<td>1.30 inches</td>
</tr>
<tr>
<td>Total Body Length (Half-Hemispherne Cylinder)</td>
<td>5.715 inches</td>
</tr>
<tr>
<td>Planform Area (Half-Hemisphere Cylinder)</td>
<td>14.145 inches²</td>
</tr>
</tbody>
</table>

### Tip Fin:

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clipped Delta Wing with Blunt Leading Edge</td>
<td></td>
</tr>
<tr>
<td>Root Chord</td>
<td>3.275 inches</td>
</tr>
</tbody>
</table>
**TABLE II**

**GEOMETRIC CHARACTERISTICS OF MODELS**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tip Chord</td>
<td>0.990</td>
</tr>
<tr>
<td>Span</td>
<td>4.160</td>
</tr>
<tr>
<td>Leading Edge Sweep</td>
<td>50</td>
</tr>
<tr>
<td>Leading Edge Radius</td>
<td>0.375</td>
</tr>
<tr>
<td>Thickness (Constant)</td>
<td>0.650</td>
</tr>
<tr>
<td>Area</td>
<td>9.27</td>
</tr>
<tr>
<td>Aspect Ratio</td>
<td>1.862</td>
</tr>
<tr>
<td>Taper Ratio</td>
<td>0.30/5</td>
</tr>
<tr>
<td>Thickness Ratio (Fin Root-Wing Center Plane)</td>
<td>0.199</td>
</tr>
</tbody>
</table>

**Sparier**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chord (Constant)</td>
<td>0.650</td>
</tr>
<tr>
<td>Snea</td>
<td>30.70</td>
</tr>
<tr>
<td>Height</td>
<td>0.611</td>
</tr>
<tr>
<td>Planform Area</td>
<td>6.96</td>
</tr>
<tr>
<td>Bottom Cylinder Radius</td>
<td>0.325</td>
</tr>
<tr>
<td>TAP NUMBER</td>
<td>X'</td>
</tr>
<tr>
<td>------------</td>
<td>------</td>
</tr>
<tr>
<td>78</td>
<td>0.030</td>
</tr>
<tr>
<td>79</td>
<td>0.10</td>
</tr>
<tr>
<td>80</td>
<td>0.2396</td>
</tr>
<tr>
<td>81</td>
<td>0.4038</td>
</tr>
<tr>
<td>82</td>
<td>0.5481</td>
</tr>
<tr>
<td>83</td>
<td>0.6923</td>
</tr>
<tr>
<td>84</td>
<td>0.8077</td>
</tr>
<tr>
<td>85</td>
<td>0.9173</td>
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<tr>
<td>86</td>
<td>0.9750</td>
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<tr>
<td>87</td>
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<td>93</td>
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<td>94</td>
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<tr>
<td>97</td>
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<td>98</td>
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</tr>
<tr>
<td>99</td>
<td></td>
</tr>
<tr>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>

All pressure taps are located with respect to the virtual apex, and the vertical center plane, of the model. Pressure taps 26 — 88 are on the lower (fix-plate) surface and taps 126 — 184 are on the upper surface of the model.
<table>
<thead>
<tr>
<th>CONFIGURATION</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Basic Configuration (Wing-Body)</td>
</tr>
<tr>
<td></td>
<td>Wing - Clipped delta wing, spherically blunted apex, cylindrically blunted leading edges, blunt base</td>
</tr>
<tr>
<td></td>
<td>+ Body - Overslung, half conical forebody and half-cylindrical afterbody</td>
</tr>
<tr>
<td>IV</td>
<td>Basic + Tip Fins</td>
</tr>
<tr>
<td></td>
<td>(I)</td>
</tr>
<tr>
<td>VII</td>
<td>Wing - Clipped delta wing, spherically blunted apex, cylindrically blunted leading edges, blunt base</td>
</tr>
<tr>
<td></td>
<td>+ Body - Overslung, half-hemispherical forebody and half-cylindrical afterbody</td>
</tr>
<tr>
<td></td>
<td>+ Spoiler - Plug type, trailing edge spoiler</td>
</tr>
<tr>
<td>VIII</td>
<td>VII + Tip Fins</td>
</tr>
</tbody>
</table>
Separated Flow ahead of a Ramp
Fore and aft flaps, end plates
3 separate models:
1) Pressure and heat transfer, AEDC Tunnels
   A & B, M = 5 & 8
2) Controlled wall temperature, pressure,
   AEDC Tunnel B, M = 8
3) Pressure and heat transfer, Grumman Shock
   Tunnel, M = 13 & 19

Wedge - Plate Interaction
Small and large fin with sharp and blunt leading edges
2 separate models:
1) Pressure and heat transfer, AEDC Tunnels
   A & B, M = 5 & 8
2) Pressure and heat transfer, Grumman Shock
   Tunnel, M = 13 & 19

Clipped Delta, Blunt L.E.,
Center body, T.E. flaps, drooped nose,
Stoiler, tip fins
3 separate models:
1) Pressure and heat transfer, AEDC Tunnels
   A & B, M = 5 & 8
2) Pressure, AEDC Ramsesh 2,
   M = 19
3) Six component force, AEDC Tunnels
   A & B, M = 5 & 8

Delta, Blunt L.E., sub-convex
T.E. flaps, canard, ventral fin
3 separate models:
1) Pressure and heat transfer, AEDC Tunnels
   A & B, M = 5 & 8
2) Pressure and heat transfer, Grumman Shock
   Tunnel, M = 19
3) Six component force, AEDC Tunnels
   A & B, M = 5 & 8

Fig. 1a General Outline of Models and Remarks for Over-all Program
Fig. 1c  Configuration IV - Basic Wing-Body + Tip Fins
(for dimensions see Figure 1b)
Fig. 1d Configuration VII - Wing - Blunt Body + Full Span Plug Spoiler
(for dimensions see Figure 1b)
Fig. 1e Configuration VII - Wing - Blunt Body + Full Span Plug Spoiler + Tip Fins
(for dimensions see Figures 1b, 1c, 1d)
Fig. 1f Pressure Tap Location and Model Coordinate System
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Figure 18  Photograph - Actuator Assembly

(1) Electric Motors, (2) Potentiometers,
(3) Lead Screws, (4) Control Rods
(5) Water Cooled Bulkheads
Fig. 2 Sign Convention for Model Angles and Control Deflection Angles
Fig. 3 Configuration 1, $\alpha = 0$, $y_1 = 6.3 = 0$

a) $C_p$ vs. $X$, lower surface
b) $C_p$ vs. $Y'$, upper surface
c) $C_p$ vs. $X$, lower surface
d) $C_p$ vs. $Y'$, upper surface

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Fig. 3 Configuration $t_1 = 0$, $t_2 = t_3 = 410$

a) $C_p \sim x'$, lower surface
b) $C_p \sim x'$, upper surface
c) $C_p \sim y'$, lower surface
d) $C_p \sim y'$, upper surface
Fig. 3  Configuration 1, \( \alpha = 0 \), \( \beta = \beta_3 = +20 \)

1) \( C_p \) vs. \( X' \), lower surface
2) \( C_p \) vs. \( Y' \), lower surface

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Fig. 3 Configuration 1, α = 0, θ₁ = θ₂ = +20°

h) $C_p$ vs. $Y'$, upper surface

i) $C_p$ vs. $X'$, upper surface
Fig. 3  Configuration 1, $a = 0, b_2 = b_3 = +30$

(a) $C_p$ vs. $Y^*$, lower surface
(b) $C_p$ vs. $X^*$, lower surface

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Fig. 3  Configuration 1, $a = 0$, $h_2 = h_3 = 100$

a) $C_p$ vs. $Y'$, upper surface

b) $C_p$ vs. $X'$, upper surface

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Fig. 3 Configuration 1. $\alpha = 0$, $\beta = 60$.

- $C_{\mu}$ vs. $X'$, lower surface
- $C_{\mu}$ vs. $Y'$, lower surface

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Fig. 3  Configuration I, $a = 0$, $b_2 = b_3 = +39$

a) $C_p$ vs. $Y'$, upper surface
b) $C_p$ vs. $X'$, upper surface
Fig. 4  configuration  (a)  $\alpha = 0$,  $\delta = 5\eta = 10$
   a) $C_p$ vs. $x'$, lower surface
   b) $C_p$ vs. $x'$, upper surface
   c) $C_p$ vs. $y'$, lower surface
   d) $C_p$ vs. $y'$, upper surface
Fig. 4  Configuration 1,  $\alpha = 0$, $\beta_2 = \beta_3 = -20$

a) $C_p$ vs. $Y'$, lower surface
b) $C_p$ vs. $X'$, lower surface

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Fig. 4 Configuration 1, α = 0, ε₂ = ε₃ = -20

a) Cₚ vs. Y', upper surface
b) Cₚ vs. X', upper surface

(NONDIMENSIONAL STREAMWISE DISTANCE FROM VIRTUAL Apex)
Fig. 4  Configuration I,  \( \alpha = -6 \degree, \beta_3 = -30 \degree \\
1) \( C_p \) vs. \( \gamma' \), lower surface \\
2) \( C_p \) vs. \( x' \), lower surface
Fig. 4 Configuration I, $\alpha = 0$, $\phi_2 = 5^\circ$, $\phi_3 = -30$

k) $C_p$ vs. $x'$, upper surface
l) $C_p$ vs. $y'$, upper surface
Fig. 4m  Configuration 1, $\alpha = 0$, $\delta_2 = 5.3 = -39$

$C_p$ vs. $X'$, lower surface

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Fig. 6n  Configuration I, \( a = 0 \), \( b_2 = b_3 = -39 \)

\( C_p \) vs. \( X' \), upper surface

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Fig. 4  Configuration 1, $\alpha = 0, \theta_2 = \theta_3 = -39$

- o) $C_p$ vs. $Y'$, lower surface
- p) $C_p$ vs. $Y'$, upper surface
Fig. 5 Configuration 1, $c_x = 40^\circ$, $b_2 = b_3 = 0$

1) $C_p$ vs. $x'$, lower surface
2) $C_p$ vs. $x'$, upper surface
3) $C_p$ vs. $y'$, lower surface
4) $C_p$ vs. $y'$, upper surface
Fig. 5  Configuration 1, \( \alpha = \pm 10 \degree \), \( \beta_2 = \beta_3 = \pm 10 \degree 

a) \( C_p \) vs. \( X' \), lower surface 
b) \( C_p \) vs. \( X' \), lower surface
Fig. 5  Configuration I,  $\alpha = 4\,^\circ$, $\beta_2 = \beta_3 = 410$

a) $C_p$ vs. $Y'$, upper surface

b) $C_p$ vs. $X'$, upper surface
Figure 5  Configuration 1, a = +10°, c_2 = t_2 = +20°

1) C_p vs. Y', lower surface

2) C_p vs. X', lower surface

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Fig. 3 Configuration I, $a = \times 10$, $b_2 = c_3 = \times 10$

a) $C_p$ vs. $Y'$, upper surface

b) $C_p$ vs. $X'$, upper surface

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Fig. 3m  Configuration I,  $\alpha = 40^\circ$, $b_2 = b_3 = 45^\circ$

$C_p$ vs $X'$, lower surface
(NONDIMENSIONAL SEMIPHAN DISTANCE)

Fig. 5a Configuration 1, $\alpha = \pm 10$, $\theta_2 = \theta_3 = \pm 10$

$C_p$ vs. $\gamma'$, lower surface

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Fig. 5  Configuration 1, $z = +10$, $\theta = \theta_1 = +30$

- $C_p$ vs. $Y'$, upper surface
- $C_p$ vs. $X'$, upper surface
Fig. $5q$ Configuration I, $\alpha = 4^\circ$, $\theta_2 = \theta_3 = 43^\circ$

$C_p$ vs. $Y'$, lower surface
Fig. 5c  Configuration 1, $\alpha = +10^\circ$, $a_2 = a_3 = +59$
$C_p$ vs. $X'$, lower surface
Fig. 5 Configuration 1, $a = 410$, $\theta_2 = 0, \theta_3 = 439$

(a) $C_p$ vs. $\gamma'$, upper surface
(b) $C_p$ vs. $\kappa'$, upper surface

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Fig. 6 Configuration $L = 90^\circ$, $\alpha = 10^\circ$, $\beta_2 = 5^\circ$ = 10

- 1) $C_p$ vs. $\chi^*$, lower surface
- 2) $C_p$ vs. $\chi^*$, upper surface
- 3) $C_p$ vs. $\chi^*$, lower surface
- 4) $C_p$ vs. $\chi^*$, upper surface

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Fig. 6 Configuration 1, \( \alpha = -40^\circ \), \( \beta = 0 \, \circ \) -20

- a) \( C_p \) vs. \( X' \), lower surface
- b) \( C_p \) vs. \( X' \), upper surface
- c) \( C_p \) vs. \( Y' \), lower surface
- d) \( C_p \) vs. \( Y' \), upper surface

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Fig. 6  Configuration 1, $\alpha = 0^\circ$, $\beta = 0^\circ$

1) $C_p$ vs. $x'$, lower surface
2) $C_p$ vs. $x'$, upper surface
3) $C_p$ vs. $y'$, lower surface
4) $C_p$ vs. $y'$, upper surface

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Fig. 6  Configuration 1, \( \alpha = -10 \), \( \theta_2 = \theta_j = -39 \)

- \( C_p \) vs. \( X' \), lower surface
- \( C_p \) vs. \( X' \), lower surface

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Fig. 6  Configuration I, $\phi = 410^\circ$, $\delta_2 = \delta_3 = -39$

o) $C_p$ vs. $Y'$, upper surface
p) $C_p$ vs. $X'$, upper surface
Fig. 7 Configuration 1, \( \alpha = 0^\circ \), \( X = 0 \), \( y = 0 \)

- a) \( C_p \) vs. \( X' \), lower surface
- b) \( C_p \) vs. \( X' \), upper surface
- c) \( C_p \) vs. \( Y' \), lower surface
- d) \( C_p \) vs. \( Y' \), upper surface

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Fig. 7  Configuration 1,  \( \eta = \pm 20 \), \( \delta_2 = \delta_3 = \pm 10 \)

a) \( C_p \) vs. \( X' \), lower surface

f) \( C_p \) vs. \( Y' \), lower surface
Fig. 7 Configuration I, $\alpha = +20^\circ$, $b_2 = b_3 = +10$

a) $C_p$ vs. $Y'$, upper surface
b) $C_p$ vs. $X'$, upper surface

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Fig. 7 Configuration $T_{s}, \theta = -20, \theta_{2} = \theta_{3} = -20$

1) $C_p$ vs. $X'$, lower surface

2) $C_p$ vs. $X'$, upper surface

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Fig. 7 Configuration I, \( \alpha = 420 \), \( \beta_2 - \beta_3 = 420 \\n
1) \( C_p \) vs. \( Y' \), lower surface \\
2) \( C_p \) vs. \( Y' \), upper surface
Fig. 7n  Configuration I, \( \alpha = 420 \), \( \phi_2 = \phi_3 = +30 \)

\( C_p \) vs. \( Y' \), lower surface

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Fig. 7n Configuration I, $u = +20$, $v_2 = v_3 = +30$

$C_p$ vs. $X'$, lower surface
Fig. 7  Configuration I, \( \beta = 820 \), \( \theta_2 = \theta_3 = 430 \)

1) \( C_p \) vs. \( \gamma' \), upper surface
2) \( C_p \) vs. \( X' \), upper surface
(Nondimensional semi-span distance)

Figure 7e: Configuration I, $\alpha = +20^\circ$, $\beta_1 = 5_3 = +39$

$C_p$ vs. $Y'$, lower surface

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Fig. 7r: Configuration I, $\alpha = 42^\circ, \beta = \gamma = 49^\circ$

$C_p$ vs. $X'$, lower surface

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Fig. 7 Configuration I, $\alpha = +20^\circ$, $S_2 = 6.3 = +39$

a) $C_p$ vs. $Y'$, upper surface

c) $C_p$ vs. $X'$, upper surface

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FIG. 8  Configuration I, $\alpha = 6^\circ$, $\beta_2 = 0^\circ$, $\gamma = -20$

a) $C_p$ vs. $\gamma'$, lower surface

b) $C_p$ vs. $\gamma'$, lower surface
Fig. 8  Configuration I,  \( \alpha = 420 \), \( \beta_2 = \beta_3 = -10 \)

a) \( C_p \) vs. \( x' \), upper surface
b) \( C_p \) vs. \( y' \), upper surface
Fig. 8  Configuration 1, \( \alpha = -20 \), \( \beta_2 = \beta_3 = -20 \)

a) \( C_p \) vs. \( X' \), lower surface
b) \( C_p \) vs. \( Y' \), lower surface

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**Fig. 6** Configuration I, $\alpha = +20$, $\beta_2 = \beta_3 = -20$

- **g)** $C_p$ vs. $x'$, upper surface
- **h)** $C_p$ vs. $y'$, upper surface

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Fig. 8 Configuration 1a \( \alpha = +70 \), \( \delta_x = \delta_y = -30 \)

1. \( C_p \) vs. \( Y' \), lower surface

2. \( C_p \) vs. \( Y' \), lower surface
Fig. 8 Configuration I, \( \alpha \approx 420\), \( \beta_2 = \beta_3 = -35 \)

1) \( C_p \) vs. \( X' \), upper surface

2) \( C_p \) vs. \( Y' \), upper surface
Fig. 8  Configuration 1, $\alpha = -30^\circ$, $\beta_2 = \beta_3 = -30$

a) $C_p$ vs. $x'$, lower surface

b) $C_p$ vs. $y'$, lower surface
Fig. 8  Configuration I,  \( \alpha = -42^\circ \), \( \beta_2 = \beta_3 = -39 \)

a) \( C_p \) vs. \( X' \), upper surface

b) \( C_p \) vs. \( Y' \), upper surface

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Fig. 9  Configuration I, $\alpha = 30^\circ$, $\theta_2 = \theta_3 = 0$

(a) $C_p$ vs. $X$, lower surface
(b) $C_p$ vs. $X'$, upper surface

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Fig. 9 Configuration I, $\alpha = 43.0^\circ$, $\delta_2 = \delta_3 = 0$

c) $C_p$ vs. $Y'$, lower surface

d) $C_p$ vs. $Y'$, upper surface
Fig. 9  Configuration I, \(\alpha = +30^\circ\), \(h_2 = h_3 = +10\)

\(c_p\) vs. \(x'\), lower surface

\(c_p\) vs. \(x'\), upper surface

(NONDIMENSIONAL STREAMWISE DISTANCE FROM VIRTUAL APPEX)
Fig. 9  Configuration I, $\alpha = +30^\circ$, $C_1 = 0.3 - +10$

a) $C_p$ vs. $\gamma'$, lower surface

b) $C_p$ vs. $\gamma'$, upper surface
Fig. 41: Configuration 1, $\alpha = +30^\circ$, $\delta_2 = \delta_3 = +20$.

$C_p$ vs. $Y'$, lower surface.
Fig. 4j  Configuration 1, $\alpha = +30^\circ$, $b_2 = b_3 = +20^\circ$

$C_p$ vs. $X'$, lower surface
Fig. 9  Configuration 1, $c = +30', \sigma_2 = 0.3 = +20$

k) $C_p$ vs. $Y'$, upper surface

l) $C_p$ vs. $X'$, upper surface

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Fig. 7a Configuration 1, $\alpha = 45^\circ$, $\delta_2 = \delta_3 = 0$

$C_p$ vs. $\gamma'$, lower surface

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Fig. 9n  Configuration 1, $\alpha = +30$, $\theta_2 = \theta_3 = +30$

$C_p$ vs. $X'$, lower surface
Fig. 9 Configuration 1, \( \alpha = +30 \), \( \beta_2 = 52 = +30 \)

- o) \( C_p \) vs. \( Y' \), upper surface
- p) \( C_p \) vs. \( X' \), upper surface
Fig. 9c Configuration 1, α = +30, β2 = β3 = +39
Cp vs. ξ', lower surface

(CODIMENSIONAL SEMI-SPAN DISTANCE)
Fig 9c  Configuration L, $\alpha = +50^\circ$, $\beta_2 = \beta_3 = +3^\circ$

$C_p$ vs. $X'$, lower surface
Fig. 9  Configuration 1, $\alpha = 43^0$, $b_2 = b_3 = 439$

a) $C_p$ vs. $Y'$, upper surface
b) $C_p$ vs. $X'$, upper surface
Fig. 10  Configuration I,  $a = 30^\circ$, $\theta_2 = \theta_3 = -20^\circ$

a) $C_p$ vs. $Y'$, lower surface
b) $C_p$ vs. $X'$, lower surface

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Fig. 10  Configuration 1,  $\alpha = +30^\circ$, $\delta_2 = \delta_3 = -20$

c) $C_p$ vs. $Y'$, upper surface

d) $C_p$ vs. $X'$, upper surface
Fig. 10  Configuration I,  $\alpha = -30^\circ$, $\beta_1 = \beta_3 = -30$

a) $C_p$ vs. $Y'$, lower surface
b) $C_p$ vs. $X'$, lower surface

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Fig. 10 Configuration 1, α = +30°, δ₃ = -39°

g) $C_p$ vs. $Y'$, upper surface

h) $C_p$ vs. $X'$, upper surface
Fig. 11  Configuration L, $\alpha = 45^\circ$, $\alpha_2 = \alpha_3 = 0$

a) $C_p$ vs. $X'$, lower surface

b) $C_p$ vs. $X'$, upper surface
Fig. 11  Configuration I, $\alpha = 44^\circ$, $\beta_2 = \beta_3 = 0$

c) $C_p$ vs. $\gamma'$, lower surface

d) $C_p$ vs. $\gamma'$, upper surface
Fig. 11e  Configuration 1, $\alpha = +40^\circ$, $\delta_2 = \delta_3 = +10$

$C_p$ vs. $Y'$, lower surface
Fig. 11d Configurations 1, $\alpha = +60$, $\beta_2 = \beta_3 = +10$

$C_p$ vs. $X'$, lower surface
Fig. 11  Configuration I, $\alpha = 44^0$, $\delta_2 = c_2 = +10$

a) $C_p$ vs. $Y'$, upper surface

b) $C_p$ vs. $Y'$, upper surface

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Fig. 111  Configuration I, $a = 45^\circ$, $b_2 = 5, b_3 = -20$

$C_p$ vs. $Y$, lower surface

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Fig. 11j Configuration I, $a = 440, s_2 = c_3 = 420$

$C_p$ vs. $X'$, lower surface

(Nondimensional Streamwise Distance from Virtual Apex)
Fig. 11 Configuration I, $\alpha = 44^\circ$, $c_2 = c_3 = 420$

k) $C_p$ vs. $Y'$, upper surface

l) $C_p$ vs. $X'$, upper surface
Fig. 11c Configuration 4, \( a = 440 \), \( \beta = 0.5 \times 40 \)

\( C_p \) vs. \( \psi \), lower surface

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Fig. 11n  Configuration I, $\alpha = 440^\circ$, $\sigma_2 - \sigma_3 = 430$

$C_p$ vs. $X'$, lower surface

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Fig. 11 Configuration 1 \( \alpha = \pm 45^\circ, \beta_2 = \beta_3 = +30^\circ \)

a) \( C_p \) vs. \( Y' \), upper surface

b) \( C_p \) vs. \( X' \), upper surface

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Fig. 11g  Configuration I, \( \alpha = 440, S_2 = S_3 = 33 \)

\( C_p \) vs. \( Y' \), lower surface

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Fig. 11r  Configuration I, \( \alpha = +40^\circ \), \( \phi_2 = \phi_3 = +39 \)

\( C_p \) vs. \( x' \), lower surface
Fig. 11  Configuration 1, \( \alpha = 44.0 \), \( \epsilon_2 = \epsilon_3 = -39 \)

a) \( C_p \) vs. \( Y' \), upper surface

c) \( C_p \) vs. \( X' \), upper surface
Fig. 12 Configuration 1, $a \times 460$, $b_2 = 6, = -20$

a) $C_p$ vs. $Y'$, lower surface
b) $C_p$ vs. $X'$, lower surface
Contrails

\[ C_p \]

-3.5
-3.0
-2.5
-2.0
-1.5
-1.0
-0.5
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5

\[ X' \]

-0.2
-0.1
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0

Upper Surface

\[ Y' \]

-0.2
-0.1
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0

\[ \text{SYMBOL} \]

-0.5481
0.6923
0.7866
0.9173
0.9750

\( X' \) (NONDIMENSIONAL SEMISPAN DISTANCE)

\( C_p \) (NONDIMENSIONAL STREAMWISE DISTANCE FROM VIRTUAL APPEX)

Fig. 12 Configuration I, \( \alpha = 4^\circ \), \( \beta_2 = 1^\circ \), \( -20 \)

c) \( C_p \) vs. \( Y' \), upper surface

d) \( C_p \) vs. \( X' \), upper surface

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Contrails

(NONDIMENSIONAL STREAMWISE DISTANCE FROM VIRTUAL AXIS)

Fig. 12 Configuration T, \( \alpha = 44^\circ \), \( \beta = \beta_2 = -39 \)

a) \( C_p \) vs. \( X' \), lower surface
b) \( C_p \) vs. \( X' \), lower surface

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Fig. 12  Configuration T1, z = 440, \(\zeta = \frac{\omega}{3} = -39\)

- g) \(C_p\) vs. \(Y'\), upper surface
- h) \(C_p\) vs. \(X'\), upper surface

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Fig. 13a  Configuration 1,  $a = 450^\circ$, $b_2 = b_3 = 0$

$C_p$ vs. $Y$, lower surface
(NONDIMENSIONAL STREAMWISE DISTANCE FROM VIRTUAL APEX)

Fig. 13b Configuration 1, $\alpha = +50$, $\beta_2 = 0$, $\beta_3 = 0$

$C_p$ vs. $X$, lower surface

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Fig. 13  Configuration 1,  \( \alpha = 90^\circ \),  \( \beta = \gamma = 0 \)

- c)  \( C_p \) vs.  \( X' \), upper surface
- d)  \( C_p \) vs.  \( X' \), upper surface
Fig. 13a Configuration 1, $\alpha = +50, \theta_2 = \theta_3 = +10$

$C_p$ vs. $Y'$, lower surface

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Fig. 13c  Configuration 1,  $\alpha = 50^\circ$, $\beta_2 = 8^\circ$, $\gamma = 10^\circ$

$C_p$ vs. $X'$, lower surface

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Fig. 13  Configuration I, \( \alpha = \pm 50^\circ, \beta_2 = \beta_3 = \pm 10^\circ \)

- g) \( C_p \) vs. \( Y' \), upper surface
- h) \( C_p \) vs. \( X' \), upper surface

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Fig. 131 Configuration 1, \( \alpha = 45^\circ \), \( \beta_2 = \beta_3 = 420^\circ \)

\( C_p \) vs. \( \gamma \), inner surface

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Fig. 13] Configuration 1, $\alpha = 45^\circ$, $\delta_2 = \delta_3 = 42^\circ$

$C_p$ vs. $X^*$, lower surface

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Fig. 13  Configuration 1, $\alpha = +50^\circ$, $S_2 = S_3 = +20$

k) $C_p$ vs. $Y'$, upper surface

l) $C_p$ vs. $X'$, upper surface

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Fig. 1a  Configuration 1, $\alpha = +50^\circ$, $c_2 = c_3 = +59^\circ$

$C_p$ vs. $Y'$, lower surface
Fig. 13a Configuration 1, $a = 45^\circ$, $b_2 = b_3 = 90$

$C_p$ vs. $X'$, lower surface

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Fig. 13 Configuration I, $z = \pm 50$, $\delta_2 = \delta_3 = +39$

- c) $C_p$ vs. $Y'$, upper surface
- p) $C_p$ vs. $X'$, upper surface
Fig. 14  Configuration 1, $a = 45^\circ$, $\theta_2 = \theta_1 = -20$

a) $C_p$ vs. $Y'$, upper surface

b) $C_p$ vs. $X'$, lower surface
Fig. 14  Configuration I, $\alpha = +5^\circ$, $\theta_2 = \theta_3 = -20^\circ$

(c) $C_p$ vs. $Y'$, upper surface

(d) $C_p$ vs. $Y'$, lower surface
Fig. 14  Configuration 1, \( n = +45, \theta_1 = \theta_2 = -39 \)

- e) \( C_p \) vs. \( x' \), upper surface
- f) \( C_p \) vs. \( x' \), lower surface
Fig. 14  Configuration 1, $\alpha = +50^\circ$, $\delta_2 = \delta_3 = -39$

- g) $C_p$ vs. $\gamma'$, upper surface
- h) $C_p$ vs. $\gamma'$, lower surface
![Graphical Data]

### Table 15: Configuration 1, \( \alpha = -3 \), \( \beta = \gamma = 0 \)

<table>
<thead>
<tr>
<th>Symbol</th>
<th>( \frac{x}{D} )</th>
<th>( \frac{y}{D} )</th>
<th>( C_p )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.15</td>
<td>0</td>
<td>0.3441</td>
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<td>0.25</td>
<td>0.1</td>
<td>0.662</td>
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<tr>
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<td>0.45</td>
<td>0.1</td>
<td>0.7866</td>
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<tr>
<td>Upper Surface</td>
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<td>0.2</td>
<td>0.7973</td>
</tr>
<tr>
<td>Lower Surface</td>
<td></td>
<td></td>
<td>0.9712</td>
</tr>
</tbody>
</table>

- a) \( C_p \) vs. \( \frac{x}{D} \), upper surface
- b) \( C_p \) vs. \( \frac{y}{D} \), lower surface
- c) \( C_p \) vs. \( \frac{y}{D} \), upper surface
- d) \( C_p \) vs. \( \frac{y}{D} \), lower surface

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Fig. 16  Configuration 1, $a = -10\circ$, $b_2 = \theta_2 = 0$

a) $C_p$ vs. $X$, lower surface
b) $C_p$ vs. $X$, upper surface
c) $C_p$ vs. $Y$, lower surface
d) $C_p$ vs. $Y$, upper surface

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Fig. 16  Configuration 1, α = -10°, \( \delta_2 = \delta_3 = 0° \)

a) \( C'_1 \) vs. \( x' \), lower surface
b) \( C'_1 \) vs. \( y' \), upper surface
c) \( C'_2 \) vs. \( x' \), lower surface
d) \( C'_2 \) vs. \( y' \), upper surface

e) \( C'_p \) vs. \( x' \), lower surface
f) \( C'_p \) vs. \( y' \), upper surface

g) \( C'_p \) vs. \( \gamma' \), lower surface
h) \( C'_p \) vs. \( \gamma' \), upper surface

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Fig. 16  Configuration X, \( \theta = -10^\circ, \quad \phi = \psi = 0^\circ \)

1. Cp vs. \( \xi \), lower surface
2. Cp vs. \( \xi' \), lower surface
3. Cp vs. \( \xi' \), upper surface
4. Cp vs. \( \xi' \), upper surface

(!) Un dimensionless streamline distance from virtual apex

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Fig. 16 Configuration I, $\alpha = -10$, $\delta_2 = \delta_3 = +30$

m) $C_p$ vs. $Y'$, lower surface

n) $C_p$ vs. $X'$, lower surface
Fig. 16  Configuration 1,  $\alpha = -10^\circ$, $\psi = 5^\circ = +30^\circ$

a) $C_p$ vs. $Y'$, upper surface

b) $C_p$ vs. $X'$, upper surface

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Fig. 16 Configuration 4, $\alpha = -20$, $\chi = \chi' = 49$

1) $C_p$ vs. $Y'$, lower surface
2) $C_p$ vs. $X'$, lower surface
Fig. 16  Configuration I, $\alpha = -15^\circ$, $S_2 = S_3 = 499$

1) $C_p$ vs. $X'$, upper surface
2) $C_p$ vs. $X'$, upper surface

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Fig. 17  Configuration 1,  $\alpha = -10^\circ$, $5\text{a}_1-5\text{a}_3 = -10$

- (a) $C_p$ vs. $Y'$, lower surface
- (b) $C_p$ vs. $X'$, lower surface

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Fig. 17  Configuration I, $a = -10^\circ$, $b = c = -10$

(c) $C_p$ vs. $Y'$, upper surface
(d) $C_p$ vs. $X'$, upper surface
Fig. 17  configuration I,  \( \alpha = -10 \), \( r_2 = b_3 = -20 \)

- c) \( C_p \) vs. \( Y' \), lower surface
- f) \( C_p \) vs. \( X' \), lower surface
Fig. 17 Configuration I, $\alpha = -10^\circ$, $\beta_1 = \beta_2 = -20^\circ$

- g) $C_p$ vs. $y'$, upper surface
- h) $C_p$ vs. $x'$, upper surface

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Fig. 17  Configuration $i$, $\alpha = -10$, $b_2 = b_3 = -30$

1) $C_p$ vs. $Y'$, lower surface

2) $C_p$ vs. $X'$, lower surface
Fig. 17k  Configuration I,  $\alpha = -10°, \gamma_2 = \gamma_3 = -30°$

$C_p$ vs. $Y'$, upper surface
Fig. 171 Configuration I, $\alpha = -40^\circ$, $c_2 = c_3 = -30$

$C_p$ vs. $X'$, upper surface
Fig. 17 Configuration 1, $\alpha = -10^\circ$, $\beta_2 = \beta_3 = -39$

m) $C_p$ vs. $Y'$, lower surface
n) $C_p$ vs. $X'$, lower surface

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Fig. 17c  Configuration I, $\alpha = -30^\circ$, $\beta_2 = \gamma_3 = -30$

$C_p$ vs. $\gamma'$, upper surface

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Contrails

(NONDIMENSIONAL STREAMWISE DISTANCE FROM VIRTUAL APEX)

Fig. 17p  Configuration I, $\alpha = -10^\circ$, $\delta_2 - \delta_3 = -39$

$C_p$ vs. $X'$, upper surface

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Fig. 18  Configuration $\alpha = -15$, $C = H = 0$

a) $C$ vs. $\alpha'$, lower surface

b) $C$ vs. $\alpha'$, upper surface
c) $C$ vs. $\alpha'$, lower surface
d) $C$ vs. $\alpha'$, upper surface
Fig. 19  Configuration 1,  $\alpha = -20^\circ, \beta_2 = \beta_3 = 0$

a) $C_p$ vs. $Y'$, lower surface

b) $C_p$ vs. $X'$, lower surface

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Fig. 19 Configuration I, $\alpha = -30$, $\beta_2 = \beta_3 = 0$

1) $C_p$ vs. $X'$, upper surface
2) $C_p$ vs. $Y'$, upper surface
Fig. 19  Configuration $z$, $a = -20$, $b_2 = b_3 = +10$

c) $C_p$ vs. $Y'$, lower surface

$C_p$ vs. $X'$, lower surface
Fig. 19  Configuration 1, $\alpha = -20^\circ$, $b_2 = b_3 = +10$

a) $C_p$ vs. $\gamma'$, upper surface
b) $C_p$ vs. $X'$, upper surface
Fig. 19  Configuration 2, $a = -20$, $\delta_2 = \delta_3 = 420$

1) $C_p$ vs. $Y'$, lower surface
2) $C_p$ vs. $X'$, lower surface
Fig. 19  Configuration 1, \( \alpha = -20 \), \( z_2 = 0 \), \( \theta = 420 \)

1) \( C_p \) vs. \( X' \), upper surface

2) \( C_p \) vs. \( Y' \), upper surface

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Fig. 15 Configuration 1, $\alpha = 20^\circ$, $\beta = 3^\circ = +30$

- $C_p$ vs. $Y'$, lower surface
- $C_p$ vs. $X'$, lower surface
Fig. 19 Configuration I, $\alpha = -20$, $\beta_2 = 8 \times 10^{-3}$

a) $C_p$ vs. $Y'$, upper surface

b) $C_p$ vs. $X'$, upper surface

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Fig. 18 Configuration 1, $\alpha = -20^\circ, \delta_2 = \delta_3 = 0^\circ$

1) $C_p$ vs. $Y'$, lower surface
2) $C_p$ vs. $X'$, lower surface
Fig. 19  Configuration I, $a = -2^\circ$, $c_2 = n_1 = 430$

a) $C_p$ vs. $Y'$, upper surface
b) $C_p$ vs. $X'$, upper surface

c Approved for Public Release
Fig. 20 Configuration 1, $\alpha = -20^\circ$, $\theta_2 = \theta_3 = -10$^

a) $C_p$ vs. $Y'$, lower surface  
b) $C_p$ vs. $X'$, lower surface
Fig. 20  Configuration 1,  $\alpha = -20$, $\beta_2 = 63 = -10$

a) $C_p$ vs. $Y'$, upper surface

b) $C_p$ vs. $X'$, upper surface
Fig. 20 Configuration I, \( \alpha = -20 \), \( \beta_2 = \beta_3 = -20 \)

- a) \( C_p \) vs. \( Y' \), lower surface
- f) \( C_p \) vs. \( X' \), lower surface

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Fig. 20g. Configuration I, \( \alpha = -20^\circ \), \( \delta_2 = \delta_3 = -20^\circ \)

\( C_p \) vs. \( X' \), Upper surface
Confirons

Fig. 20b  Configuration: h = -20, h_2 = h_3 = -20
C_p vs. X', upper surface

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Fig. 20  Configuration I, $\alpha = -20$, $\delta_2 = \delta_3 = -30$

1) $C_p$ vs. $Y'$, lower surface
2) $C_p$ vs. $X'$, lower surface
Fig. 20k: Configuration 1, $\alpha = -20^\circ$, $\delta_2 = \delta_3 = -30^\circ$

$C_p$ vs. $\gamma'$, upper surface

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Fig. 201  Configuration 1, \( \alpha = -20 \), \( \theta_2 = \theta_3 = -30 \)

\( C_p \) vs. \( X' \), upper surface
Fig. 20 Configuration 1, $a = -20, b_2 = b_3 = -35$

a) $C_p$ vs. $Y'$, lower surface

b) $C_p$ vs. $Y'$, lower surface
Fig. 20c Configuration 1, \( \alpha = -20^\circ \), \( \theta_1 = \theta_2 = -39 \)

\( c_p \) vs. \( x' \), upper surface

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Fig. 20p  Configuration 1, α = -20°, θ₂ = θ₃ = -39°

Cₚ vs. X', upper surface

(NONDIMENSIONAL STREAMWISE DISTANCE FROM VIRTUAL Apex)
Fig. 21 Configuration 1, α = -25°, $\theta_2 = \theta_3 = 0$

- C\textsubscript{p} vs. $\chi'$, lower surface
- C\textsubscript{p} vs. $\chi$, lower surface
Fig. 21 Configuration I, $\alpha = -25^\circ, \delta_2 = \delta_3 = 0$

- $C_p$ vs. $Y'$, upper surface
- $C_p$ vs. $X'$, upper surface

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Contraits

Fig. 22 Configuration 1, α = -30, δ = 0

a) $C_p$ vs. $Y'$, lower surface
b) $C_p$ vs. $X'$, lower surface

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Fig. 2: Configuration 1, \( \alpha = -30 \), \( \beta_2 = \beta_3 = 0 \\ 
(a) \( C_p \) vs. \( Y' \), upper surface \\
(b) \( T_p \) vs. \( X' \), upper surface 

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Fig. 22 Configuration 1, \( \alpha = -30 \), \( \delta_2 = \delta_3 = +20 \)

- \( C_p \) vs. \( Y' \), lower surface
- \( C_p \) vs. \( X' \), lower surface

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Fig. 22  Configuration 1, $\theta = -30$, $\phi_2 = \phi_3 = \pm 90$

a) $C_p$ vs. $T'$, upper surface  
b) $C_p$ vs. $X'$, upper surface
Fig. 22 Configuration I, $\alpha = -30^\circ$, $\beta_2 = \beta_3 = +30^\circ$

1) $C_p$ vs. $Y'$, lower surface

2) $C_p$ vs. $X'$, lower surface
Fig. 22  Configuration 1, $a = -30$, $b_2 = b_3 = +30$

k) $C_p$ vs. $Y'$, upper surface
l) $C_p$ vs. $X'$, upper surface

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Fig. 22. Configuration 7, $\alpha = -30$, $x_2 = x_3 = -39$

n) $C_p$ vs. $Y'$, lower surface
n) $C_p$ vs. $X'$, lower surface
Fig. 22  Configuration 1, $\alpha = -30, \beta_2 = \beta_3 = 439$

a) $C_p$ vs. $Y'$, upper surface

b) $C_p$ vs. $X'$, upper surface

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Fig. 23  Configuration I, $\alpha = -30$ deg, $\alpha_2 = -30$ deg

a) $C_p$ vs. $x'$, lower surface
b) $C_p$ vs. $x'$, upper surface

(NONDIMENSIONAL STREAMWISE DISTANCE FROM VIRTUAL APEX)
Fig. 23  Configuration 1, $a = -30^\circ$, $b_2 = b_3 = -10$

(c) $C_p$ vs. $Y'$, lower surface

d) $C_p$ vs. $Y'$, upper surface
Fig. 23  Configuration I,  \( \alpha = -30 \),  \( \beta_2 = \beta_3 = -20 \)

- e)  \( C_p \) vs. \( \gamma' \), lower surface
- f)  \( C_p \) vs. \( \chi' \), lower surface
Fig. 23a. Configuration 1, \( \alpha = -30 \), \( \theta_z = \theta_y = -20 \)

\( C_p \) vs. \( \gamma' \), upper surface

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Fig. 23a Configuration I, \( \alpha = -30 \), \( \delta_2 = \delta_3 = -20 \)

\( C_p \) vs. \( x' \), upper surface

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Fig. 23  Configuration I, $\alpha = -30^\circ$, $b_2 \cdot c_3 = -30$

1) $c_p$ vs. $y'$, lower surface
2) $c_p$ vs. $x'$, lower surface

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Fig. 23k  Configuration 1, $\alpha = -30$, $\delta_2 = \delta_3 = -30$

$c_p$ vs. $Y'$, upper surface
Fig. 231  Configuration I, \( \theta = -30 \), \( \theta_2 = \gamma_2 = -30 \)

\( C_p \) vs. \( x' \), upper surface

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Fig. 23 Configuration I, $\alpha = -30$, $\delta_2 = 5.3 = -39$

- $C_p$ vs. $Y'$, lower surface
- $C_p$ vs. $X'$, lower surface

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Fig. 230  Configuration 1, $\alpha = -30^\circ$, $\theta_2 = -30^\circ$

$C_p$ vs. $Y'$, upper surface
Fig. 23p  Configuration I, $\alpha = 30^\circ$, $h_2 = h_3 = -39$

$C_p$ vs. $X'$, upper surface

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Fig. 24  Configuration I,  \( \alpha = -35 \), \( b_2 = s_3 = -30 \)

a)  \( C_p \) vs. \( Y' \), lower surface

b)  \( C_p \) vs. \( X' \), lower surface
Fig. 26c Configuration 1, \( \alpha = -35 \), \( \beta_2 = \beta_3 = -30 \)

\( C_p \) vs. \( Y' \), upper surface
Fig. 24d Configuration I, \( a = -35 \), \( b_2 = b_3 = -30 \)

\( C_p \) vs. \( X' \), upper surface
Fig. 25 Configuration 4, $\alpha = -40^\circ$, $\gamma_2 = \gamma_3 = 0$

(a) $C_p$ vs. $x'$, lower surface

(b) $C_p$ vs. $x'$, upper surface

(Approved for Public Release)
Fig. 15  Configuration I, \( \alpha = -60 \), \( \beta_2 - \beta_3 = 0 

- c) \( C_p \) vs. \( Y' \), lower surface
- d) \( C_p \) vs. \( Y' \), upper surface

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Fig. 15 Configuration T, \( \alpha = 45^\circ \), \( \beta_2 = \beta_3 = 0^\circ \)
a) \( C_p \) vs. \( X' \), lower surface
b) \( C_p \) vs. \( X' \), upper surface
Fig. 25  Configuration I, $\alpha = -60, c_2 - c_3 = +20$

g) $C_p$ vs. $y'$, lower surface

h) $C_p$ vs. $y'$, upper surface

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Fig. 23 Configuration 1, $\alpha = -60$, $\beta_2 = 0$, $\alpha_3 = +50$

1) $C_p$ vs. $x'$, lower surface

2) $C_p$ vs. $x'$, upper surface

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Fig. 25  Configuration I, $\alpha = -40, \beta_2 = \beta_3 = +30$

- $C_p$ vs. $Y'$, lower surface
- $C_p$ vs. $Y'$, upper surface

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Fig. 25 Configuration 1, \( \alpha = -60^\circ, \theta_2 = 60^\circ, \theta_3 = 45^\circ \)
- (a) \( C_\theta \) vs. \( X \), lower surface
- (b) \( C_\theta \) vs. \( X \), upper surface

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Fig. 22  Configuration I, \( a = -40, b_2 = b_3 = -39 \)

- C_p vs. \( Y' \), lower surface
- C_p vs. \( Y' \), upper surface

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Fig. 26 Configuration 1, $\alpha = -60^\circ$, $\delta_2 = -10$

a) $C_p$ vs. $X'$, lower surface

b) $C_p$ vs. $X'$, upper surface
Fig. 26  Configuration 1, $\alpha = -45^\circ$, $\beta_2 = \beta_3 = -10$

- c) $C_p$ vs. $Y'$, lower surface
- d) $C_p$ vs. $Y'$, upper surface
Fig. 26   Configuration I,  u = -45, \beta_2 = \beta_3 = -20

a) \( C_p \) vs. \( Y' \), lower surface
f) \( C_p \) vs. \( X' \), lower surface
Fig. 26g  Configuration 1, $\alpha = -60^\circ$, $b_2 = b_3 = -20$
$C_p$ vs. $Y'$, upper surface

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Fig. 26b. Configuration 1, $\alpha = -40$, $\delta_1 = \delta_3 = -20$

$C_p$ vs. $X'$, upper surface
Fig. 26  Configuration I,  $\alpha = -40^\circ, \beta_2 = \beta_3 = +30^\circ$

1) $C_p$ vs. $y'$, lower surface
2) $C_p$ vs. $x'$, lower surface
Fig. 26k  Configuration I, \( \alpha = -60^\circ, C_2 = 0.30 \)

\( C_p \) vs. \( Y' \), upper surface
Fig. 261: Configuration 1, $\alpha = -40^\circ$, $c_2 = c_3 = -20$

$c_p$ vs. $x'$, upper surface
Fig. 26 Configuration I, \( \alpha = -40 \), \( t_2 = t_3 = -35 \)

a) \( C_p \) vs. \( Y' \), lower surface

b) \( C_p \) vs. \( X' \), lower surface

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Fig. 26a Configuration I, $u = -40$, $b_2 = b_3 = -39$

$C_p$ vs. $Y'$, upper surface
Fig. 26p  Configuration I, \( q = -40 \), \( \delta_2 = 0 \), \( \delta_3 = -30 \)

\( C_p \) vs. \( X' \), upper surface
Fig. 27 Configuration 1, $a = .50$, $\delta_x = \delta_y = 0$

a) $C_p$ vs. $x'$, lower surface  
b) $C_p$ vs. $x'$, upper surface
Fig. 27 Configuration I, $\alpha = -50^\circ, b = 0^\circ$

e) $C_p$ vs. $\gamma'$, lower surface

d) $C_p$ vs. $\gamma'$, upper surface
Fig. 27  Configuration 1,  a = -50° , z_2 = 0°.  

(a)  $C_p$ vs. $X'$, lower surface

(b)  $C_p$ vs. $X'$, upper surface

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Fig. 27  Configuration I, α = -50°, δ2 = δ3 = 4°20′

- C_p vs. Y', lower surface
- C_p vs. Y', upper surface
Fig. 27 Configuration 1, $a = -50$, $c_2 = c_3 = a30$
1) $C_p$ vs. $X'$, lower surface
2) $C_p$ vs. $X'$, upper surface

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Fig. 27  Configuration 1, \( \alpha = -50 \), \( \gamma_2 = \frac{\gamma_3}{2} = 436 \\
(1)  C_p vs. \gamma', upper surface \\
(2)  C_p vs. \gamma', lower surface
Fig. 27 Configuration 1, $\alpha = -5^\circ$, $\delta = \gamma = 0^\circ$

a) $C_p$ vs. $x'$, lower surface

b) $C_p$ vs. $x'$, upper surface

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Fig. 27 Configuration I, \( \alpha = -50 \), \( \beta_2 = \beta_3 = 45^\circ 

a) \( C_p \) vs. \( \eta' \), lower surface

b) \( C_p \) vs. \( \eta' \), upper surface

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Fig. 28 Configuration 1, \( \alpha = -50^\circ, \beta_2 = \beta_3 = -10^\circ \)

a) \( C_p \) vs. \( Y' \), lower surface

b) \( C_p \) vs. \( X' \), lower surface

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Fig. 28c: Configuration 1, \( \alpha = 30^\circ \), \( \sigma_2 = \sigma_3 = -10^\circ \)

\( C_p \) vs. \( \gamma' \), upper surface

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Fig. 28d Configuration I, $\alpha = -50$, $\beta_2 = \beta_3 = -10$

$C_p$ vs. $X'$, upper surface

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Fig. 28 Configuration 1, $\alpha = -20$, $\beta_2 = 0$, $\gamma = -20$

- c) $C_p$ vs. $X'$, lower surface
- f) $C_p$ vs. $Y'$, lower surface
Fig. 28g Configuration I, $\alpha = -50^\circ$, $\beta_2 = \beta_3 = -20$

$C_p$ vs. $\gamma'$, upper surface
Fig. 28b: Configuration I, $\alpha = -70^\circ$, $t_2 = t_3 = -20$

$C_p$ vs. $X'$, upper surface
Fig. 28  Configuration I, $\alpha = -30^\circ$, $v_2 = v_3 = -30$

1) $C_p$ vs. $Y'$, lower surface
2) $C_p$ vs. $X'$, lower surface
Fig. 28k  Configuration 1, \( \alpha = -50 \degree \), \( \epsilon_2 = \epsilon_3 = -30 \)

\( C_p \) vs. \( Y' \), upper surface

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Fig. 201 Configuration 1, $\phi = -30$, $\theta_2 = 0$, $\theta_3 = -30$

$C_p$ vs. $X'$, upper surface

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Fig. 28  Configuration 1,  $\alpha = -30$, $\alpha_2 = \alpha_3 = -30$

a) $C_p$ vs. $Y'$, lower surface

b) $C_p$ vs. $X'$, lower surface
Fig. 28a  Configuration 1, $\alpha = -50^\circ$, $\beta = \gamma = -3^\circ$

$C_p$ vs. $y'$, upper surface
Fig. 28b  Configuration I,  \( \alpha = -50 \), \( \beta_2 = \delta_3 = -39 \)

\( C_p \) vs. \( X' \), upper surface
Fig. 29 Configuration IV, c = 0, $\theta_2 = 15 = 0$

a) $C_p$ vs. $\gamma'$, lower surface
b) $C_p$ vs. $\gamma'$, upper surface
c) $C_p$ vs. $x'$, lower surface
d) $C_p$ vs. $x'$, upper surface

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Fig. 29 Configuration IV, \( a = 0, b_2 = b_3 = \#10 \)

a) \( C_p \) vs. \( y' \), lower surface

f) \( C_p \) vs. \( x' \), lower surface

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Fig. 29  Configuration IV, $\alpha = 0$, $62 = +10$

- g) $C_p$ vs. $\gamma'$, upper surface
- h) $C_p$ vs. $\chi'$, upper surface

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Fig. 28  Configuration IV, \( \theta = 0 \), \( \alpha_2 = \alpha_3 = \pm 20 \)

1) \( C_p \) vs. \( Y' \), lower surface

2) \( C_p \) vs. \( X' \), lower surface

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Fig. 29  Configuration IV,  $\alpha = 0$, $\delta_2 = \delta_3 = \pm 20$

b) $C_p$ vs. $Y'$, upper surface

1) $C_p$ vs. $X'$, upper surface
Fig. 29 Configuration IV, $\alpha = 0$, $\beta_2 = \beta_3 = +30$

a) $C_p$ vs. $Y'$, lower surface

b) $C_p$ vs. $X'$, lower surface
Fig. 29  Configuration IV,  $\alpha = 0, \ x_2 = x_3 = \pm 30$

a) $C_p$ vs. $y'$, upper surface

b) $C_p$ vs. $x'$, upper surface
Fig. 29q. Configuration IV, $\alpha = 0$, $\delta_2 = \frac{\pi}{3} = 0.52$, $C_{p}$ vs. $Y'$, lower surface.
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fig. 29c Configuration TV, \( \alpha = 0 \), \( \alpha_2 + \alpha_3 = \pm 30 \)

\( C_p \) vs. \( X' \), lower surface
Fig. 29 Configuration IV, $\alpha = 0$, $\delta_2 = \delta_3 = 499$

a) $c_p$ vs. $y'$, upper surface

b) $c_p$ vs. $x'$, upper surface
Fig. 30 Configuration IV: $\alpha = 0$, $\delta_2 = \delta_3 = -10$

a) $C_p$ vs. $y'$, lower surface
b) $C_p$ vs. $y'$, upper surface
c) $C_p$ vs. $x'$, lower surface
d) $C_p$ vs. $x'$, upper surface

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Contrails

Fig. 30 Configuration IV, $a = 0$, $\delta_2 = 0.3 = -20$

- e) $C_p$ vs. $Y'$, lower surface
- f) $C_p$ vs. $X'$, lower surface

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Fig. 30  Configuration IV, $\alpha = 0, \beta_2 = \beta_3 = 20$

a) $C_p$ vs. $Y'$, upper surface

b) $C_p$ vs. $X'$, upper surface

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Fig. 30  Configuration IV, \( \alpha = 0 \), \( \delta_2 = 0.3 \), -30

1) \( C_p \) vs. \( Y' \), lower surface
2) \( C_p \) vs. \( X' \), lower surface
Fig. 30 Configuration IV, $\alpha = 0^\circ$, $T_2 = T_3 = -30$

1) $C_p$ vs. $T'$, upper surface
2) $C_p$ vs. $X'$, upper surface

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Fig. 30 Configuration IV, \( n = 0 \), \( \theta = 2 \theta = -30 \)

a) \( C_p \) vs. \( \eta' \), lower surface

b) \( C_p \) vs. \( \chi' \), lower surface

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Fig. 30  Configuration IV, $u = 0$, $s_2 = s_3 = -30$

1) $C_p$ vs. $\eta'$, upper surface
Fig. 30 Configuration IV, $a = 0$, $A_3 = 8.3 = -39$

p) $C_p$ vs. $X'$, upper surface
Fig. 31 Configuration IV, z = 420, x = y = 0

a) $C_p$ vs $Y'$, lower surface
b) $C_p$ vs $Y'$, upper surface
c) $C_p$ vs $X'$, lower surface
d) $C_p$ vs $X'$, upper surface

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Fig. 31  Configuration IV.  $\alpha = 4\circ$, $\beta = 5\circ = 10\circ$

1) $C_p$ vs. $Y'$, lower surface
2) $C_p$ vs. $X'$, lower surface

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Fig. 31 Configuration IV, $\alpha = +10^\circ$, $\beta_2 = -10^\circ$

- g) $C_p$ vs. $Y'$, upper surface
- h) $C_p$ vs. $X'$, upper surface
Fig. 311. Configuration IV, $\alpha = +40^\circ$, $a_3 = b_3 = +20$

$C_p$ vs. $\gamma'$, lower surface
Fig. 31j Configuration II, \( \alpha = 45^\circ \), \( C_2 \cdot 53 = 420 \)

\( C_p \) vs. \( x' \), lower surface
Fig. 31  Configuration IV, \( z = +10 \), \( b_2 = b_3 = +20 \)

1) \( C_p \) vs. \( Y' \), upper surface
2) \( C_p \) vs. \( X' \), upper surface
Fig. 31a  Configuration IV, \( \alpha = \pm 10 \), \( \varphi_2 = \varphi_3 = \pm 30 \)

*\( C_p \) vs. \( \psi' \), lower surface
Fig. 31a Configuration IV, $\alpha = 45^\circ$, $\delta_2 = \delta_3 = -30^\circ$

$C_p$ vs. $\xi'$, lower surface

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Fig. 31  Configuration IV, α = +10°, β₂ = β₃ = +30°

- o) $C_p$ vs. $\Gamma'$, upper surface
- p) $C_p$ vs. $X'$, upper surface
Fig. 3lc Configuration IV, $\alpha = +20^\circ$, $M_2 = 0.53$

$C_p$ vs. $Y'$, lower surface
Fig. 31  Configuration IV, $a = +10, b_2 = c_2 = +39$

a) $C_p$ vs. $Y'$, upper surface
b) $C_p$ vs. $X'$, upper surface

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Fig. 32 Configuration \( \beta_c = 20^\circ, \alpha = 215^\circ, h_2 = h_3 = -30^\circ \)

a) \( C_p \) vs. \( Y \), lower surface

b) \( C_p \) vs. \( Y \), upper surface

c) \( C_p \) vs. \( X \), lower surface

d) \( C_p \) vs. \( X \), upper surface
Fig. 32 configuration IV. $x = 900, x_2 + y_2 = -20$

a) $C_p$ vs. $x'$, lower surface
b) $C_p$ vs. $x'$, upper surface

c) $C_p$ vs. $x'$, lower surface

d) $C_p$ vs. $x'$, upper surface

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Fig. 32  Configuration IV,  \( \alpha = +10 \), \( \beta = 6.3 \cdot \cdot -30 

1) \( C_p \) vs. \( V' \), lower surface  
2) \( C_p \) vs. \( V' \), upper surface  
3) \( C_p \) vs. \( X' \), lower surface  
4) \( C_p \) vs. \( X' \), upper surface

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Fig. 32  Configuration IV,  \( \alpha = +10^\circ \),  \( \beta_1 = \beta_2 = -30^\circ \)

a)  \( C_p \) vs.  \( Y' \), lower surface

b)  \( C_p \) vs.  \( X' \), lower surface
Fig. 32 Configuration 4: $\alpha = 45^\circ$, $\theta_2 = \frac{b_3}{b} = -39$

a) $C_p$ vs. $\gamma'$, upper surface

b) $C_p$ vs. $\lambda'$, upper surface

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Fig. 33  Configuration IV, $\alpha = 42^\circ$, $y' = z' = 0$

a) $C_p$ vs. $y'$, lower surface
b) $C_p$ vs. $x'$, lower surface
Fig. 31 Configuration IV, $\alpha = -20^\circ$, $a_2 = 0.3 = 0$

a) $C_p$ vs. $y'$, upper surface
b) $C_p$ vs. $x'$, upper surface

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Fig. 53e  Configuration IV,  $\alpha = +20^\circ$, $\theta_2 = \theta_3 = +40^\circ$

$C_p$ vs. $\xi'$, lower surface
Fig. 33f  Configuration IV, \( \alpha = +20 \), \( \beta_2 = \beta_3 = +10 \)

\( C_p \) vs. \( X' \), lower surface
Fig. 33 Configuration IV, \( \alpha = +25 \), \( \beta = \gamma = +10 \)

a) \( C_p \) vs. \( y' \), upper surface

b) \( C_p \) vs. \( X' \), upper surface

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Fig. 331. Configuration IV, $\alpha = 420$, $a_2 = a_3 = 420$

$C_p$ vs. $Y'$, lower surface
Fig. 33j  Configuration IV, \( \alpha = +20 \), \( \beta_2 = \beta_3 = +20 \)

\( C_p \) vs. \( X' \), lower surface

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Fig. 33 Configuration IV, \( \alpha = 42^\circ \), \( e_2 = n_2 = 920 \\

k) \ C_p \ vs. \ Y', \ upper \ surface \\

l) \ C_p \ vs. \ X', \ upper \ surface
Fig. 33a  Configuration IVb,  \( \alpha = +20 \),  \( \delta_2 = 0 \),  \( \delta_3 = +30 \)

\( C_p \) vs. \( Y' \), lower surface
Fig. 33a Configuration IV, \( \alpha = +20^\circ \), \( \phi_2 = +30^\circ \)

\( C_p \) vs. \( x' \), lower surface

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Fig. 33 Configuration IV, $\alpha = 420$, $\psi_2 = 8.5$, $x = 30$

(a) $C_p$ vs. $Y^+$, upper surface
(b) $C_p$ vs. $X^+$, upper surface
Fig. 33q  Configuration IV, $\alpha = 42^\circ$, $\theta_2 = \theta_3 = 43^\circ$

$C_p$ vs. $T'$, lower surface
Fig. 33r Configuration IV, $\alpha = 42^\circ$, $\beta_2 = \beta_3 = 45^\circ$

$C_p$ vs. $x'$, lower surface
Fig. 33  Configuration IV, $\alpha = 420^\circ$, $h_2 = e_1 = 439$

a) $C_p$ vs. $Y'$, upper surface

b) $C_p$ vs. $X'$, upper surface

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Fig. 34  Configuration IV, $\alpha = 42^\circ$, $h_2 = h_3 = -10$

a) $C_p$ vs. $Y'$, lower surface

b) $C_p$ vs. $X'$, lower surface
Fig. 34  Configuration IV, \( \alpha = +20 \), \( \delta_2 = \delta_3 = -10 \)

a) \( C_p \) vs. \( Y' \), upper surface

b) \( C_p \) vs. \( X' \), upper surface
Fig. 34 Configuration IV, $\alpha = +20 \degree$, $\delta_2 = \delta_3 = -20$

- e) $C_p$ vs. $Y'$, lower surface
- f) $C_p$ vs. $X'$, lower surface
Fig. 54 Configuration IV, $\alpha = +20$, $\beta_j = -20$

- (g) $C_p$ vs. $X'$, upper surface
- (h) $C_p$ vs. $X'$, upper surface
Fig. 34  Configuration IV, $\alpha = 42^\circ$, $s_2 = c_2 = -30$

1) $C_p$ vs. $\gamma'$, lower surface

2) $C_p$ vs. $X'$, lower surface
Fig. 34  Configuration IV, $\alpha = +60^\circ$, $\beta_2 = \beta_3 = -30^\circ$

k) $\varepsilon_y$ vs. $X'$, upper surface

l) $C_p$ vs. $X'$, upper surface

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Fig. 34 Configuration IV, \( \alpha = \pm 20 \), \( \delta_2 = \delta_3 = -39 \)

a) \( C_p \) vs. \( y' \), lower surface

b) \( C_p \) vs. \( x' \), lower surface
Fig. 54  Configuration IV, $\alpha = +20^\circ$, $b_2 = b_3 = -39$

- o) $C_p$ vs. $y'$, upper surface
- p) $C_p$ vs. $x'$, upper surface
Fig. 35 Configuration IV, $\alpha = 0^\circ$, $b_2 = 0$, $x_2 = 0$

a) $C_p$ vs. $Y'$, lower surface

b) $C_p$ vs. $X'$, lower surface

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Fig. 35  Configuration IV, $\alpha = 30^\circ$, $\delta_2 = \delta_3 = 0$

- c) $C_p$ vs. $Y'$, upper surface
- d) $C_p$ vs. $X'$, upper surface
Fig. 35e  Configuration IV,  α = +30°, β₁ × β₂ = 410

Cₚ vs. Y', lower surface

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Fig. 32f Configuration IV, $\alpha = +30^\circ$, $\beta_2 = \beta_3 = +10^\circ$

$C_p$ vs. $X'$, lower surface

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Fig. 35 Configuration IV, \( \alpha = +30^\circ, \theta_2 = \delta_3 = +10 \)

- g) \( C_p \) vs. \( y' \), upper surface
- h) \( C_p \) vs. \( x' \), upper surface
Fig. 35 Configuration IV, \( \alpha = 45^\circ \), \( \beta_2 = \beta_3 = 42^\circ \)

1) \( c_p \) vs. \( x^* \), lower surface
2) \( c_p \) vs. \( y^* \), lower surface

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Fig. 35  Configuration IV, $\alpha = 45^\circ$, $\delta_s = 6.0^\circ$, $\phi = 20^\circ$

k) $C_p$ vs. $Y'$, upper surface

l) $C_p$ vs. $X'$, upper surface
Fig. 39a Configuration IV, $\alpha = +30$, $\beta_2 = \beta_3 = +30$

$C_p$ vs. $Y'$, lower surface
Fig. 3a: Configuration IV, \( \alpha = \pm 30 \), \( \beta_2 = \beta_3 = \pm 30 \)

\( C_p \) vs. \( X' \), lower surface
Fig. 3b Configuration IV, $\alpha = +30, \beta = \beta_3 \approx +30$

- o: $C_p$ vs. $y'$, upper surface
- p: $C_p$ vs. $x'$, upper surface
Fig. 3jq  Configuration IV, $a = 430, \theta_2 = 0.3\theta_1 = 0.35$

$c_p$ vs. $Y'$, lower surface
Fig. 35c  Configuration IV, $\alpha = +30^\circ$, $\beta_3 = \delta_3 = +39$

$C_p$ vs. $X'$, lower surface
**Fig. 35** Configuration IV, $\alpha = +30^\circ$, $\delta = c = +39$

- $C_p$ vs. $Y'$, upper surface
- $C_p$ vs. $X'$, upper surface

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Fig. 36  Configuration IV, $\alpha = +30^\circ$, $\delta_2 = \delta_3 = -20$

a) $C_p$ vs. $Y'$, lower surface
b) $C_p$ vs. $X'$, lower surface
Fig. 36  Configuration IV, $\alpha = +30^\circ$, $\beta = 0^\circ$, $\gamma = -20$

c) $C_p$ vs. $Y'$, upper surface

d) $C_p$ vs. $X'$, upper surface
Fig. 36 Configuration IV, $\alpha = +30^\circ, \beta_2 = \beta_3 = -39$

- $C_p$ vs. $\gamma'$, lower surface
- $C_p$ vs. $\sigma'$, lower surface

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Fig. 36  Configuration IV, $\alpha = +30^\circ$, $b_2 = b_3 = -39$

a) $C_p$ vs. $Y'$, upper surface
b) $C_p$ vs. $X'$, upper surface
Fig. 37a  Configuration IV, $\alpha = 90^\circ$, $\beta_1 = \beta_3 = 0$

$C_p$ vs. $Y'$, lower surface

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Fig. 37b  Configuration IV, $\alpha = 44.0^\circ$, $b_2 = b_3 = 0$

$C_p$ vs. $X'$, lower surface

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Fig. 37 Configuration IV, $\alpha = +40^\circ$, $h_2 = 5.3 = 0$

c) $C_p$ vs. $Y'$, upper surface

d) $C_p$ vs. $X'$, upper surface
Fig. 37a. Configuration IV, \(\alpha = 46^\circ\), \(\varepsilon_2 = 0.3 = +10\)

\(C_p\) vs. \(Y^*\), lower surface
Fig. 31f  Configuration IV, \( \alpha = \pm 60 \), \( u_2 = u_3 = \pm 10 \)

\( C_p \) vs. \( X' \), lower surface
Fig. 37  Configuration IV, \( \alpha = 44^\circ \), \( \delta_2 = \delta_3 = 4^\circ 

\( g \)  \( C_p \) vs. \( \gamma' \), upper surface

\( h \)  \( C_p \) vs. \( X' \), upper surface
Fig. 3) Configuration IV, $\alpha = 46\degree$, $\delta_2 = \delta_3 = 420$

1) $C_p$ vs. $z'$, lower surface

3) $C_p$ vs. $z'$, lower surface
Fig. 37 Configuration IV, $\alpha = 4^\circ$, $\delta_2 = \delta_3 = 40$

1) $C_p$ vs. $Y'$, upper surface
2) $C_p$ vs. $X'$, upper surface
Fig. 57c: Configuration IV, $\alpha = 14^\circ$, $\delta_2 = 6^\circ$, $\delta_3 = 43^\circ$

$C_p$ vs. $Y'$, lower surface
Fig. 37n  Configuration IV, $\alpha = 45^\circ$, $\theta_2 = 5.3 = 6.0$

$C_p$ vs. $X'$, lower surface

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Fig. 37  Configuration IV, $\alpha = +40^\circ$, $\delta_2 = \delta_3 = +30^\circ$

o) $C_p$ vs. $Y'$, upper surface

p) $C_p$ vs. $X'$, upper surface

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Fig. 37q  Configuration IV, $\alpha = 45^\circ$, $\gamma_2 = \phi_2 = 45^\circ$

$C_p$ vs. $\tau'$, lower surface

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Fig. 37c Configuration IV, \( \alpha = 440^\circ, \beta_2 = \beta_3 = 439^\circ \)

\( C_p \) vs. \( Y' \), lower surface

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Fig. 37 Configuration IV, θ = 440, v₁ = 5.3 = 439
a) \( C_P \) vs. \( Y' \), upper surface
b) \( C_P \) vs. \( X' \), upper surface

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Fig. 33a  Configuration IV, $\alpha = 44^\circ$, $t_2 = \delta_3 = -20$

$C_p$ vs. $Y'$, lower surface
Fig. 38b  Configuration IV,  $\alpha = 44.0^\circ$, $\beta_2 = \beta_3 = -20$

$C_p$ vs. $X'$, lower surface

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Fig. 38 Configuration IV, $\alpha = 46^\circ$, $c_2 = c_3 = -20$

a) $C_p$ vs. $Y'$, upper surface
b) $C_p$ vs. $X'$, upper surface
Fig. 38e  Configuration IV, $\alpha = 40^\circ$, $T_2 = T_3 = -39$

$C_p$ vs. $Y'$, lower surface
Fig. 38f  Configuration IV,  $\alpha = 45^\circ$, $\theta_1 = 0.5 = -39$

$C_p$ vs. $X'$, lower surface
Fig. 30  Configuration IV, \( \alpha = +40^\circ, b_1 = 0, b_3 = -39 \)

- g) \( C_p \) vs. \( Y' \), upper surface
- h) \( C_p \) vs. \( X' \), upper surface
Fig. 39a  Configuration IV, $\alpha = \pm 50^\circ$, $\psi_2 = \psi_3 = 0$

$C_p$ vs. $\chi^*$, lower surface
Fig. 39b  Configuration IV, $\alpha = 45^\circ$, $\gamma_1 = \gamma_3 = 0$

$C_p$ vs. $X'$, lower surface

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Fig. 39  Configuration IV:  $\alpha = 45^\circ$, $c_2 = c_3 = 0$

e) $C_P$ vs. $\gamma'$, upper surface

d) $C_P$ vs. $X'$, upper surface

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Fig. 39c Configuration IV, $\alpha = 45^\circ$, $U_2 = V_3 = 0$

$C_p$ vs. $Y'$, lower surface
Fig. 39i  Configuration IV, \( \alpha = +50\), \( \delta_2 = \delta_3 = +20\)
\(C_p\) vs. \(X'\), lower surface.
Fig. 39 Configuration IV, $\sigma = 0.50$, $b_2 = b_3 = 425$

a) $C_p$ vs. $Y'$, upper surface
b) $C_p$ vs. $X'$, upper surface

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Fig. 391 Configuration IV, \( \alpha = 45^\circ \), \( \theta_2 = \theta_3 = 439^\circ 
\]

\[ C_p \propto Y', \text{lower surface} \]
Fig. 39J  Configuration IV, \( \alpha = +50 \), \( \delta_2 = \delta_3 = 45^\circ \)

\[ C_p \] vs. \( x' \), lower surface

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Fig. 39  Configuration IV,  \( \alpha = +50^\circ, \ c_2 = 5.3 = 439 \)

k) \( C_p \) vs. \( Y' \), upper surface

l) \( C_p \) vs. \( X' \), upper surface

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Fig. 30a  Configuration IV, \( \alpha = 42^\circ \), \( \delta_2 = \delta_3 = -20 \)

\( \text{C}_p \) vs. \( Y' \), lower surface
Fig. 39a Configuration IΓ, \( \alpha = +50 \), \( \theta_2 = \theta_3 = -20 \)

\( C_p \) vs. \( \chi' \), lower surface

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Fig. 39  Configuration 21,  \( \alpha = +50^\circ, \beta = \angle_{3} = -20^\circ \\
  c) C_p \text{ vs. } Y', \text{ upper surface}  \\
p) C_p \text{ vs. } X', \text{ upper surface}
Fig. 39q  Configuration IV, $\alpha = +90^\circ$, $\delta_2 = \delta_3 = -39$

$C_p$ vs. $\gamma'$, lower surface
Fig. 30r. Configuration IV, $\alpha = +30^\circ$, $\lambda_2 = 0$, $\theta_\infty = -39$

$C_p$ vs. $X'$, lower surface
Fig. 39 Configuration IV, \(\alpha = 50^\circ\), \(\beta_2 = \beta_3 = -39^\circ\)

- C_p vs. \(Y'\), upper surface
- C_p vs. \(X'\), upper surface
Fig. 6a  Configuration IV, \( \phi = -10 \), \( \beta_2 \times \beta_3 = 0 
\)

a) \( C_p \) vs. \( y' \), lower surface

b) \( C_p \) vs. \( y' \), upper surface

c) \( C_p \) vs. \( X' \), lower surface

d) \( C_p \) vs. \( X' \), upper surface

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Fig. 60 Configuration IV. \( a = -10 \), \( t_2 = t_3 = 10 \)

1) \( C_p \) vs. \( y' \), lower surface
2) \( C_p \) vs. \( y' \), upper surface
3) \( C_p \) vs. \( x' \), lower surface
4) \( C_p \) vs. \( x' \), upper surface

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FIG. 40  Configuration IV, 5 = -30°, d = 1.0 = 0°

1) $C_y$ vs. $Y'$, lower surface
2) $C_p$ vs. $Y'$, upper surface
3) $C_y$ vs. $X'$, lower surface
4) $C_p$ vs. $X'$, upper surface

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Fig. 60  Configuration II, $\alpha = -10^\circ, \beta_2 = \beta_3 = +30^\circ$

- $C_p$ vs. $Y'$, lower surface
- $C_p$ vs. $Y'$, upper surface
- $C_p$ vs. $X'$, lower surface
- $C_p$ vs. $X'$, upper surface

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Fig. 40 Configuration IV, \( \alpha = -10^\circ, \beta_2 = \beta_3 = 0^\circ \)

1) \( C_p \) vs. \( Y' \), lower surface

2) \( C_p \) vs. \( X' \), lower surface

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Fig. 40  Configuration IV, $\alpha = -10^\circ$, $M = 4.2$

- $C_p$ vs. $Y'$, upper surface
- $C_q$ vs. $X'$, upper surface

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Fig. 41  Configuration IV, $a = -10$, $b_2 = 8$, $c_2 = -10$

a) $C_p$ vs. $y'$, lower surface

b) $C_p$ vs. $x'$, lower surface

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Fig. 41  Configuration IV, $\alpha = -10, \delta_2 = \delta_3 = -10$

- (c) $C_P$ vs. $Y'$, upper surface
- (d) $C_P$ vs. $X'$, upper surface

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Fig. 41 Configuration IV, \( a = -20 \), \( \delta_2 = 3\), \( \delta_3 = -20 \)

1) \( C_p \) vs. \( X' \), lower surface
2) \( C_p \) vs. \( X' \), lower surface
Fig. 41g  Configuration IV, \( \alpha = -10 \), \( \beta = \gamma = -20 \)

\( C_p \) vs. \( \eta' \), upper surface

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Fig. 6b  Configuration IV, $a = -10^\circ$, $\delta_2 = \delta_3 = -20$

$C_p$ vs. $X'$, upper surface

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**Contrails**

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**Graph Description**

- **Title:** (Nondimensional SemiSpan Distance)

- **Axes:**
  - Y': Nondimensional Streamwise Distance from Virtual Apex
  - X': Nondimensional Streamwise Distance from Leading Edge

- **Symbols:**
  - ○: Data Point
  - □: Data Point

- **Data Points:**
  - Y': 0.0, 0.0025, 0.0825, 0.0820
  - X': 0.5, 0.5, 0.6, 0.6, 0.7, 0.7, 0.8, 0.8, 0.9, 0.9

- **Legend:**
  - C_p vs. Y', lower surface
  - C_p vs. X', lower surface

---

**Fig. 41** Configuration IV, α = -30°, θ = 0°, θ = -30°

- i) C_p vs. Y', lower surface
- j) C_p vs. X', lower surface

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Fig. 61k  Configuration IV, $\alpha = -10^\circ, \theta_1 = \theta_2 = -30^\circ$

$C_p$ vs. $Y'$, upper surface
Fig. 411 Configuration $N_a$, $\alpha = -30^\circ$, $\beta_2 - \beta_4 = -30$

$C_p$ vs. $z'$, upper surface

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Fig. 41Configuration IV, $\alpha = -10^\circ, \beta = 0, \gamma = -39$

a) $C_p$ vs. $Y'$, lower surface
b) $C_p$ vs. $X'$, lower surface
Fig. 42b  Configuration IV,  $\alpha = -10$, $\theta_{2} = \theta_{3} = -35$

$C_{p}$ vs. $Y'$, upper surface

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Fig. 41p Configuration IVa, $\alpha = -10$, $b_2 = b_3 = -39$

$C_p$ vs. $X'$, upper surface

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Fig. 42 Configuration IV, $\alpha = -20$, $\delta_2 = 6_3 = 0$

a) $C_p$ vs. $Y'$, lower surface
b) $C_p$ vs. $X'$, lower surface

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Fig. 42 Configuration IV, $\alpha = -20^\circ$, $\nu_2 = \nu_3 = 0$

- $C_p$ vs. $Y'$, upper surface
- $C_p$ vs. $X'$, upper surface
Fig. 67 Configuration TV, $\alpha = -25^\circ$, $\delta = 4^\circ$

- $c_p$ vs. $y'$, lower surface
- $c_p$ vs. $y'$, upper surface
- $c_p$ vs. $x'$, lower surface
- $c_p$ vs. $x'$, upper surface

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Fig. 42 Configuration IV, $\alpha = -20^\circ, \beta_2 = \beta_3 = +20^\circ$

1) $C_p$ vs. $Y^*$, lower surface
2) $C_p$ vs. $Y^*$, upper surface
3) $C_p$ vs. $X^*$, lower surface
4) $C_p$ vs. $X^*$, upper surface
Fig. 62  Configuration IV, \( \alpha = -20 \), \( \delta_2 = \delta_1 = 450 

- c_p vs. \( y' \), lower surface
- c_p vs. \( y' \), upper surface
- c_p vs. X', lower surface
- c_p vs. X', upper surface

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Fig. 43 Configuration IV, $\alpha = -20^\circ$, $s_2 = b_3 = -10$

a) $C_p$ vs. $Y'$, lower surface

b) $C_p$ vs. $X'$, lower surface
Fig. 43c  Configuration IV.  $\alpha = -20^\circ$, $\delta_2 = \delta_3 = -10^\circ$

$C_p$ vs. $Y'$, upper surface
Fig. 43d Configuration IV, $\alpha = -20$, $\delta_2 = \delta_3 = -10$

$C_p$ vs. $x'$, upper surface

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Fig. 43  Configuration IV, $\alpha = -20$, $t_2 = s_3 = -20$

a) $C_p$ vs. $Y'$, lower surface

f) $C_p$ vs. $X'$, lower surface
Fig. 47g  Configuration IV, \( \alpha = -20, \beta_2 = \beta_3 = -20 \)

\( C_p \) vs. \( Y' \), upper surface
(NOMODIMENSIONAL STREAMWISE DISTANCE FROM VIRTUAL APPEX)

Fig. 4.3h  Configuration IV, $\alpha = -20$, $t_2 = 8_3 = -20$

$C_p$ vs. $x'$, upper surface.

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Fig. 43 Configuration IV, $\gamma = -20, \beta_2 = \beta_3 = -30$

1) $C_p$ vs. $Y'$, lower surface

3) $C_p$ vs. $X'$, lower surface
Fig. 431 Configuration IV, $\alpha = -20^\circ, \beta_2 = \beta_3 = -30^\circ$

$C_p$ vs $X'$, upper surface
Fig. 63 Configuration IV, $\alpha = -20$, $\delta_2 = \delta_3 = -39$

a) $C_p$ vs. $Y'$, lower surface
b) $C_p$ vs. $X'$, lower surface
Fig. 43c Configuration IV, $\alpha = -20^\circ$, $\ell_2 = \ell_3 = -39$

$C_p$ vs. $Y'$, upper surface

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Fig. 63p  Configuration IV,  $\alpha = -20^\circ, \theta_2 = \theta_3 = -39^\circ$

$C_p$ vs. $X'$, upper surface

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Fig. 44  Configuration IV, \( \alpha = -30^\circ \), \( \varphi_2 = \varphi_3 = 0 \)

a) \( C_p \) vs. \( y' \), lower surface

b) \( C_p \) vs. \( x' \), lower surface
Fig. 44c  Configuration IVa  $\alpha = -30^\circ$, $\delta_2 = \delta_3 = 0$

$C_p$ vs. $Y'$, upper surface

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Fig. 44d  Configuration IV, $\alpha = -30^\circ$, $\delta_1 = \delta_2 = 0$

$C_p$ vs. $X'$, upper surface
Fig. 44  Configuration IV, $\alpha = -30^\circ$, $b_2 = b_3 = +20$

a) $C_p$ vs. $Y'$, lower surface

f) $C_p$ vs. $X'$, lower surface
Fig. 46  Configuration IV: $i = +30$, $b_1 = b_2 = +20$

a) $c_p$ vs. $Y'$, upper surface

b) $c_p$ vs. $X'$, upper surface
Fig. 44 Configuration IV, $\alpha = -30^\circ$, $t_2 = t_1 = 439$

1) $C_p$ vs. $X'$, lower surface
2) $C_p$ vs. $X'$, lower surface

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Fig. 44  Configuration IV, $\alpha = -30^\circ$, $\beta_2 = \beta_3 = +30^\circ$

k) $C_p$ vs. $Y'$, upper surface

1) $C_p$ vs. $X'$, upper surface

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Contrails

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\[ C_p \]

\[ x' \]

\( y' \)

\( C_p \)

\( x' \)

\( y' \)

(NON DIMENSIONAL SEMIPAN DISTANCE)

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\( \#18, 45 \) Configuration IV, \( \alpha = -30 \), \( \delta_2 = \tau_3 = -10 \)

a) \( C_p \) vs. \( y' \), lower surface

b) \( C_p \) vs. \( x' \), lower surface

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Fig. 5c: Configuration IV, $\alpha = -30^\circ$, $b_2 = c_3 = -10$

$C_p$ vs. $Y'$, upper surface
(Nondimensional Streamwise Distance from Virtual Apex)

Figure 45: Configuration IV, \( \alpha = -30 \), \( b_2 = b_3 = -1.0 \)

\( C_p \) vs. \( X' \), upper surface
Fig. 45  Configuration IV, $\alpha = -30$, $c_2 = c_3 = -20$

- $C_p$ vs. $Y'$, lower surface
- $C_p$ vs. $X'$, lower surface
Fig. A5g  Configuration IV, $\alpha = -30^\circ$, $\theta_2 = \theta_3 = -30$

$C_p \ vs. \ Y'$. upper surface
Contamination

Figure 43b: Configuration IV, $\alpha = -30^\circ$, $\beta = \gamma = -20$

$C_p$ vs. $X'$, upper surface

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Fig. 45 Configuration IV, $\alpha = -30^\circ$, $\beta_2 = \beta_3 = -30^\circ$

1) $C_p$ vs. $\gamma'$, lower surface
2) $C_p$ vs. $X'$, lower surface

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Fig. 45a: Configuration IV, $\alpha = -30$, $\beta_2 = \beta_3 = -30$

$C_p$ vs. $Y'$, upper surface
Fig. 451  Configuration IV, α = -30, β = 0, γ = -30

$c_p$ vs. $X$, upper surface

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Fig. 45 Configuration IV, $a = -30$, $b_2 = b_3 = -39$

1. $c_p$ vs. $Y'$, lower surface
2. $c_p$ vs. $X'$, lower surface
Fig. 45e Configuration IV, $\alpha = -30^\circ$, $\beta_2 = -18^\circ$ = -39

$c_p$ vs. $\gamma$, upper surface
Fig. 65p  Configuration IV, $\alpha = -30, \beta_2 = \beta_3 = -30$

$C_p$ vs. $X'$, upper surface

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Fig. 46 Configuration IV, $u = -40$, $S_2 \times S_3 = 0$

a) $C_p$ vs. $y'$, lower surface

b) $C_p$ vs. $x'$, lower surface
Fig. 46c Configuration IV, $a = -60^\circ$, $b_2 \cdot c_3 = 0$

$C_p$ vs. $y'$, upper surface
Fig. 46d  Configuration IV, $\alpha = -40^\circ, \beta_2 = \beta_3 = 0$

$C_p$ vs. $X'$, upper surface

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Fig. 46  Configuration IV, $\alpha = -40^\circ, b_2 = t_3 = 420$

e) $C_p$ vs. $Y'$, lower surface

f) $C_p$ vs. $X'$, lower surface
Fig. 44g  Configuration IV, $\alpha = -40^\circ$, $S_2 = S_3 = 20$

$C_p$ vs. $Y'$, upper surface
Fig. 40h  Configuration IV, \( \phi = -40^\circ, \beta_2 - \beta_3 = +20 \)

\( c_p \) vs. \( X' \), upper surface
Fig. 46 Configuration IV, $\alpha = -4^\circ$, $\beta = \delta = -3^\circ$

1) $C_p$ vs. $Y'$, lower surface
2) $C_p$ vs. $X'$, lower surface
Fig. 45k  Configuration IV, $\alpha = -40, \delta_2 = \delta_3 = 45^\circ$

$c_p$ vs. $\Gamma'$, upper surface

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Fig. 461  Configuration IV, $\alpha = -40$, $\gamma_2 - \gamma_3 = +39$

$C_p$ vs. $X'$, upper surface
Fig. 47 Configuration IV, $\alpha = 40^\circ$, $5 = 0.3 = -10$

a) $C_p$ vs. $\psi'$, lower surface
b) $C_p$ vs. $\lambda'$, lower surface

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Fig. 47c Configuration IV, α = -60°, δ2 = 0°, δ3 = -10°
C_p vs. Y', upper surface
Contrails

Fig. 4/6 Configuration IV, $\alpha = 45^\circ$, $b_2 = b_3 = -10$

$C_p$ vs. $X'$, upper surface

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Fig. 47 Configuration TV, $\alpha = -40^\circ$, $\delta_3 = 5^\circ$, $\gamma = -20$

e) $C_p$ vs. $Y'$, lower surface
f) $C_p$ vs. $X'$, lower surface
Fig. 47g Configuration IV, \( \alpha = -40^\circ, \beta_2 = \beta_3 = -20 \)

\( C_p \) vs. \( Y' \), upper surface
Fig. 47h Configuration IV, $\alpha = -40^\circ, \beta_2 = \beta_3 = -20$

$C_p$ vs. $X'$, upper surface
Fig. 47  Configuration IV, α = -40°, β₂ = β₃ = -30

1) $C_p$ vs. $Y'$, lower surface
2) $C_p$ vs. $X'$, lower surface
Fig. 47k Configuration IV, $\alpha = -40$, $\beta_2 = \beta_3 = -30$

$C_p$ vs. $\zeta'$, upper surface

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Fig. 471  Configuration XI, $\alpha = -40^\circ, \beta_1 = 0^\circ, \theta = 0\circ$

$C_p$ vs. $X'$, upper surface

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Fig. 47 Configuration IV, $\alpha = -60^\circ$, $\delta_2 = \delta_3 = -30^\circ$

n) $C_p$ vs. $Y'$, lower surface
n) $C_p$ vs. $X'$, lower surface

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Fig. 47c  Configuration TV, \( \alpha = -40 \), \( \beta_2 = \beta_3 = -30 \)

\( C_p \) vs. \( Y' \), upper surface
Fig. 47b Configuration IV, $a = -60^\circ$, $b_2 = b_3 = -39$

$C_p$ vs. $X'$, upper surface

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Fig. 48 Configuration IV, $\alpha = -50$, $\delta_2 = \delta_3 = 0$

a) $C_p$ vs. $\gamma'$, lower surface

b) $C_p$ vs. $X'$, lower surface
Fig. 48c Configuration IV, $\alpha = -50$, $\delta_2 = \delta_3 = 0$
$C_p$ vs. $Y'$, upper surface
Fig. 48a  Configuration IV, $\alpha = -50^\circ$, $\theta_2 = \theta_3 = 0$

$C_p$ vs. $x'$, upper surface
Fig. 48  Configuration IV, $\alpha = -50^\circ$, $\beta_2 = \beta_3 = +20$

a) $C_p$ vs. $y'$, lower surface

f) $C_p$ vs. $x'$, lower surface

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Fig. 48g  Configuration IV, $\alpha = -59^\circ$, $\delta_\| = \delta_\perp = 0^\circ$

$C_p$ vs. $Y'$, upper surface

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Fig. 42b  Configuration IVs  $\alpha = -90^\circ$, $\delta_2 = 5\beta = 420$

$C_p$ vs. $X$, upper surface

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Fig. 68  Configuration IV, $a = -50$, $b_2 = 0.3 = -39$

1) $C_p$ vs. $Y'$, lower surface

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Fig. 4.8k Configuration IV, $\alpha = -50, \beta_2 = \beta_3 = +39$

$C_p$ vs. $Y'$, upper surface

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Fig. 481  Configuration IV,  $\alpha = -50^\circ$, $\theta = 83^\circ = +39$

$C_p$ vs. $X'$, upper surface

(Non-dimensional streamwise distance from virtual apex)
Fig. 49  Configuration IV, $\alpha = -50$, $\delta_2 = 0.3 = -10$

a) $C_p$ vs. $y'$, lower surface

b) $C_p$ vs. $x'$, lower surface
Fig. 49c  Configuration IV, $\alpha = -50^\circ$, $b_2 = b_3 = -10$
$C_D$ vs. $\gamma'$, upper surface
Fig. 49d Configuration IV, $\alpha = -90^\circ$, $\xi_2 = \xi_3 = -10$

$C_p$ vs. $X'$, upper surface
Fig. 49 Configuration IV, \( \alpha = -50 \), \( \beta_2 = \beta_3 = -20 \)

c) \( C_p \) vs. \( Y' \), lower surface

d) \( C_p \) vs. \( X' \), lower surface

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Fig. 59g  Configuration IV, $\alpha = -50$, $e_2 = e_3 = -20$

$C_p$ vs. $V'$, upper surface
Fig. 49b Configuration IV, $\alpha = -30^\circ$, $\beta_2 = \beta_3 = -20$
$C_p$ vs. $X'$, upper surface
Fig. 49  Configuration IV, \( \alpha = -50 \), \( \delta_2 = \delta_3 = -30 \)

1) \( C_p \) vs. \( Y' \), lower surface

2) \( C_p \) vs. \( X' \), lower surface
Fig. 49k  Configuration IV, $\alpha = -50^\circ$, $\beta_2 = \phi_2 = -30$

$C_p$ vs. $\Upsilon'$, upper surface
Fig. 491 Configuration IV, $\alpha = -50$, $\theta_2 = 5^\circ = -30$

$C_p$ vs. $X'$, upper surface
Fig. 49  Configuration IV, $\alpha = -50, \beta_2 = \beta_3 = -39$

m) $C_p$ vs. $Y'$, lower surface

n) $C_p$ vs. $X'$, lower surface
Fig. 59c  Configuration IV, $\alpha = -50^\circ$, $\beta_2 = \beta_3 = -30^\circ$

$C_p$ vs. $Y'$, upper surface
Fig. 49p  Configuration IV.  $\alpha = -30$, $\theta_2 = \theta_3 = -30$

$C_p$ vs. $X'$, upper surface

(Approved for Public Release)
Fig. 50 Configuration VII, Spoiler On

a) $C_p$ vs. $Y'$, $a = 0$, $Re_{/ft \times 10^{10}} = 3.3$, lower surface

b) $C_p$ vs. $X'$, $a = 0$, $Re_{/ft \times 10^{10}} = 3.3$, lower surface

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Fig. 50  Configuration VII, Spoiler On

a) \( C_p \) vs. \( \gamma' \), \( \alpha = 0 \), \( Re \_\alpha/ftx10^{-6} = 3.3 \), upper surface

b) \( C_p \) vs. \( x' \), \( \alpha = 0 \), \( Re \_\alpha/ftx10^{-6} = 3.3 \), upper surface
Fig. 50  Configuration VII, Spoiler On:

- e) $C_p$ vs. $Y'$, $\alpha = -10^\circ$, $Re_{\infty}/ft\times10^{6} = 3.3$, lower surface
- f) $C_p$ vs. $X'$, $\alpha = -10^\circ$, $Re_{\infty}/ft\times10^{6} = 3.3$, lower surface
Fig. 50  Configuration VII, Spools On

a) $C_p$ vs. $Y^+$, $\alpha = -10^\circ$, $Re_\infty/ft\times10^4 = 3.3$, upper surface

b) $C_p$ vs. $X^+$, $\alpha = -10^\circ$, $Re_\infty/ft\times10^4 = 3.3$, upper surface
Fig. 50  Configuration VII, Spoiler On

1) $C_p$ vs. $y'$, $\alpha = -20$, $Re_{\theta}/ft \times 10^{16} = 3.3$, lower surface

2) $C_p$ vs. $x'$, $\alpha = -20$, $Re_{\theta}/ft \times 10^{16} = 3.3$, lower surface
Fig. 50  Configuration VII, Spoiler On

b) $C_p$ vs. $Y'$, $\alpha = -20$, $Re = 10^{7}$, upper surface

i) $C_p$ vs. $X'$, $\alpha = 20$, $Re = 10^{7}$, upper surface

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Fig. 50  Configuration VII, Spolier On

a) $C_p$ vs. $Y'$, $\alpha = 0$, $Re_{/ft \times 10^6} = 1.1$, lower surface

b) $C_p$ vs. $X'$, $\alpha = 0$, $Re_{/ft \times 10^6} = 1.1$, lower surface

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Fig. 50 Configuration VII, Spoiler On

o) $C_p$ vs. $\gamma'$; $\alpha = 0$, $Re_\infty/ft^6 = 1.1$, upper surface

p) $C_p$ vs. $\xi'$; $\alpha = 0$, $Re_\infty/ft^6 = 1.1$, upper surface
Fig. 51 Configuration VIII, Spoiler \( w_b \), \( Re_{b}/ftm 10^{-6} = 3.3 \)

a) \( C_p \) vs. \( \theta' \), \( \alpha = 0 \), lower surface

b) \( C_p \) vs. \( \lambda' \), \( \alpha = 0 \), lower surface

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Fig. 51 Configuration VIII, Spoiler on, $Re_d/ftx10^6 = 3.3$

- C_p vs. $X'$, $\alpha = 0$, upper surface
- C_p vs. $X'$, $\alpha = 0$, upper surface
Fig. 51 Configuration VIII, Spooler on, $Ra_p/c_{p0}^{1/6} = 3.3$

- $C_p$ vs. $y'$, $u = -5$, lower surface
- $C_p$ vs. $x'$, $u = -5$, lower surface
Fig. 51  Configuration VIII. Smaller cone, \( Re_{/ftm3\cdot10^{-6}} = 3.3 \)

a) \( C_p \) vs. \( Y' \), \( \alpha = -5 \), upper surface

b) \( C_p \) vs. \( X' \), \( \alpha = -5 \), upper surface

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Fig. 51  Configuration VIII, Spoiler on, Reₘ/ïµₘ⁻¹⁰⁻⁶ = 3.3

1) \( C_p \) vs. \( Y' \), \( \alpha = -10 \), lower surface

2) \( C_p \) vs. \( X' \), \( \alpha = -10 \), lower surface

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Fig. 51 Configuration VIII, Spiler an, \( \text{Re}/
\text{ft mil} = 3.3 \\
1) C_p \text{ vs. } X', \; \alpha = -10, \; \text{upper surface} \\
2) C_p \text{ vs. } X', \; \alpha = -10, \; \text{upper surface}
Fig. 51. Configuration VIII, Spoil slo, Re_o/ftD10^-6 = 3,3
m) \( C_p \) vs. \( y' \), \( \alpha = 20^\circ \), lower surface
n) \( C_p \) vs. \( z' \), \( \alpha = 20^\circ \), lower surface

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Fig. 51 Configuration VIII, spooler air, Re/\text{ft} \times 10^6 = 3,500

-\( C_p \) vs. \( X' \), \( \alpha = -20 \), upper surface
-\( C \) vs. \( Y' \), \( \alpha = -20 \), upper surface

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Pressure Measurements at Mach 8 On An Aerodynamically Controllable Winged Re-entry Configuration

Pressure data were obtained at Mach 8 for a winged re-entry configuration having aerodynamic controls. The basic model consisted of a clipped delta wing with an overwing cone-cylinder body. The main controls tested were partial span trailing edge flaps. Data were also obtained on the effect of tip fins, hemisphere-cylinder body and a trailing edge spoiler. The data were obtained over an angle of attack range of -50° to +50°. Due to load limitations on the controls the unit test section Reynolds number varied from $3.3 \times 10^6$ at low angle of attack to $2.5 \times 10^6$ at high angle of attack.
hypersonic control
pressure measurements
winged re-entry
for separation
control characteristics

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