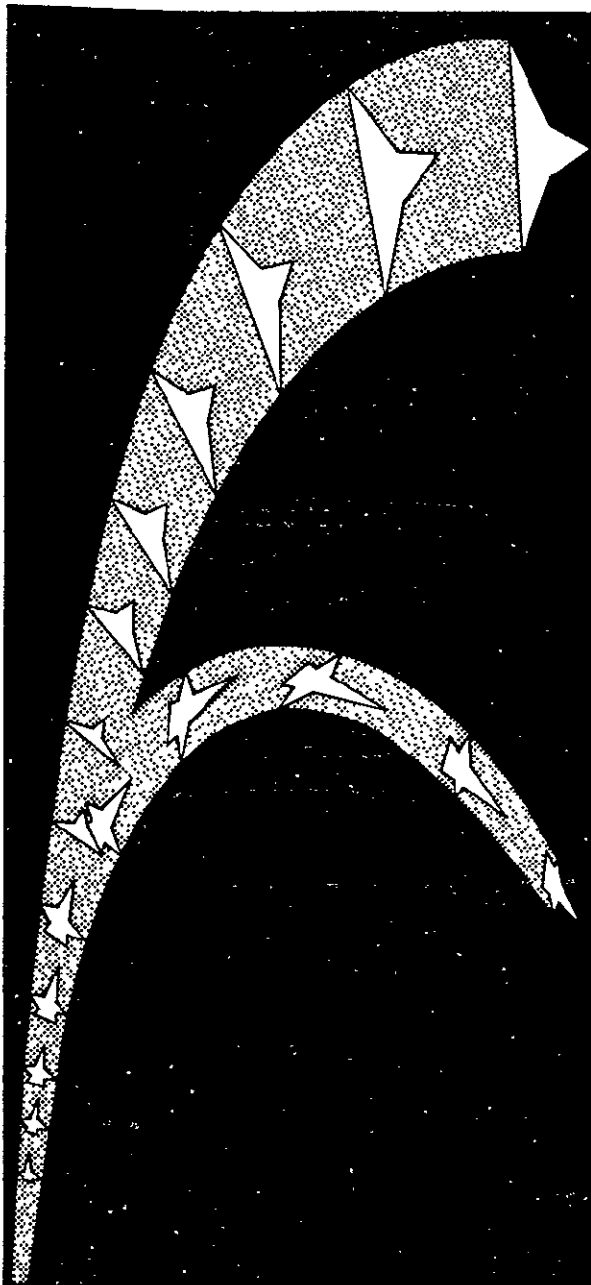


2
MMIX

DMS-DR-1154

JULY, 1971

3



—SPACE SHUTTLE—

**AERODYNAMIC HEATING TO THE
GRUMMAN SPACE SHUTTLE ORBITERS
(ROS-NB1 AND ROS-WB1) AT MACH
NUMBER 8.0**

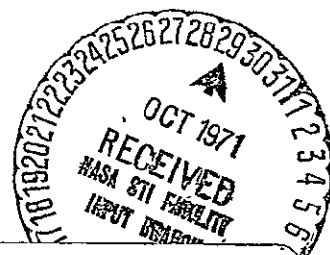
by
A. D'Errico, GAC

GAC

HYPERSONIC WIND TUNNEL

SADSAC SPACE SHUTTLE
AEROTHERMODYNAMIC
DATA MANAGEMENT SYSTEM

CONTRACT NAS8-4016
MARSHALL SPACE FLIGHT CENTER



| | | |
|-------------------|---|-------------------------|
| FACILITY FORM 602 | <i>N71-38008</i> (ACCESSION NUMBER) | _____ |
| | <i>78</i> (PAGES) | <i>G3</i> (THRU) |
| | <i>CR-119984</i> (NASA CR OR TMX OR AD NUMBER) | <i>31</i> (CODE) |
| | | <i>31</i> (CATEGORY) |

DMS-DR-1154
JULY, 1971

SADSAC/SPACE SHUTTLE
WIND TUNNEL TEST DATA REPORT

CONFIGURATION: Grumman Delta-Wing Orbiters (ROS-NBL and ROS-WBL)
TEST PURPOSE: Aerodynamic heat transfer to the space shuttle orbiter at
Mach number 8.0.
Test Hours - 80 (approx.)
TEST FACILITY: GAC Hypersonic Wind Tunnel
TESTING AGENCY: Grumman Aerospace Corporation
TEST NO. & DATE: GFHT-017, February 20 - March 22, 1971
FACILITY COORDINATOR: F. Woods
PROJECT ENGINEER(S): A. D'Errico
C. Osonitsch

DATA MANAGEMENT SERVICES

LIAISON:

John E. Vaughn
John E. Vaughn

DATA OPERATIONS:

A. D. Martin
A. D. Martin

RELEASE APPROVAL:

N. D. Kemp
FOR N. D. Kemp, Supervisor
Aero Thermo Data Group

CONTRACT NAS8-4016

AMENDMENT 151

DRL 184 - 58

This report has been prepared by Chrysler Corporation Space Division under a Data Management Contract to the NASA. Chrysler assumes no responsibility for the data presented herein other than its display characteristics.

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SPACE SHUTTLE ORBITER
HEAT TRANSFER MODEL TEST RESULTS
DATA REPORT

TEST NUMBER: GFTT-017
FACILITY: GAC HYPERSONIC WIND TUNNEL
CONFIGURATION: GRUMMAN DELTA WING ORBITERS
(ROS-NBL AND ROS-WBL)
MODEL SCALE: 0.0067
TEST PURPOSE: AERODYNAMIC HEAT TRANSFER TO THE SPACE SHUTTLE
ORBITER AT HYPERSONIC SPEEDS.
MACH NUMBER: 8.

TEST CONDUCTED BY: GRUMMAN AEROSPACE CORPORATION

TEST CONDUCTOR: A. D'ERRICO

PROJECT ENGINEER: C. OSONITSCH

TEST DATE: FEBRUARY 20 - MARCH 22, 1971

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ABSTRACT

This report presents the results of a heat transfer wind tunnel test conducted on 0.0067 scale models utilizing the phase-change paint technique. The GAC ROS-NBL and ROS-WBL delta wing orbiter configurations were investigated. The ROS-NBL configuration was tested with a ventral fin on selected runs. Data were obtained for an angle of attack range from 0 to 50 degrees.

The test was conducted in the Grumman 36 inch Hypersonic Wind Tunnel, Farmingdale, New York at a Mach Number of 8.0 and nominal Reynolds numbers per foot of 5×10^5 , 7×10^5 and 2.0×10^6 .

CONFIGURATION DATA

Components of the Orbiter Configurations were designated as follows:

| | |
|-------------------|--------------------------|
| B ₁ - | Basic body, ROS-NB1 |
| B ₂ - | Basic Body, ROS-WB1 |
| W _{1H} - | Delta Wing |
| V _{1H} - | Centerline vertical tail |
| V _{2H} - | Twin vertical tails |
| U _{1H} - | Ventral fin |

The geometric characteristics are tabulated on the model component sheets which follow. The configurations of the ROS-NB1 and ROS-WB1 delta-wing orbiter models and the ventral fin model are shown in Figures 1, 2 and 3 respectively.

MODEL COMPONENT: BODY - B₁

GENERAL DESCRIPTION: BASIC ROS-NB 1 BODY

DRAWING NUMBER: _____

DIMENSIONS:

| | <u>FULL-SCALE</u> | <u>MODEL SCALE</u> |
|----------------------|------------------------------|------------------------------|
| Length | <u>161 ft.</u> | <u>12.867 in.</u> |
| Max. Width | <u>28 ft.</u> | <u>2.240 in.</u> |
| Max. Depth | <u>28.7 ft.</u> | <u>2.296 in.</u> |
| Fineness Ratio | <u>5.61</u> | <u>5.61</u> |
| Area | | |
| Max. Cross-Sectional | <u>616 ft.²</u> | <u>3.94 in.²</u> |
| Planform | <u>3990 ft.²</u> | <u>25.54 in.²</u> |
| Wetted | <u>12610 ft.²</u> | <u>80.70 in.²</u> |
| Base | <u>590 ft.²</u> | <u>3.78 in.²</u> |

MODEL COMPONENT: BODY - B₂

GENERAL DESCRIPTION: BASIC ROS-WB1 BODY

DRAWING NUMBER: _____

DIMENSIONS:

| | <u>FULL-SCALE</u> | <u>MODEL SCALE</u> |
|----------------------|-------------------------------|------------------------------|
| Length | <u>161 ft.</u> | <u>12.867 in.</u> |
| Max. Width | <u>44.8 ft.</u> | <u>3.584 in.</u> |
| Max. Depth | <u>28.8 ft.</u> | <u>2.304 in.</u> |
| Fineness Ratio | <u>3.6</u> | <u>3.6</u> |
| Area | | |
| Max. Cross-Sectional | <u>956 ft.²</u> | <u>6.12 in.²</u> |
| Planform | <u>5160 ft.²</u> | <u>33.02 in.²</u> |
| Wetted | <u>13,930 ft.²</u> | <u>89.15 in.²</u> |
| Base | <u>744 ft.²</u> | <u>4.76 in.²</u> |

MODEL COMPONENT: W_{1H}

GENERAL DESCRIPTION: BASIC ROS-INBL WING WITH MINIMUM TRAILING EDGE THICKNESS OF 0.200 INCHES MAINTAINED FOR HEAT TRANSFER PURPOSES. LOWER SURFACE CONTOURS WERE MAINTAINED WHILE UPPER SURFACE CONTOURS WERE BLENDED TO MEET TRAILING EDGE.

DRAWING NUMBER: _____

DIMENSIONS: FULL-SCALE MODEL SCALE

TOTAL DATA

| | | |
|----------------------------|-----------------------------|------------------------------|
| Area | | |
| Planform | <u>5747 ft.²</u> | <u>36.78 in.²</u> |
| Wetted | <u>7780 ft.²</u> | <u>49.79 in.²</u> |
| Span (equivalent) | <u>97.3 ft.</u> | <u>7.784 in.</u> |
| Aspect Ratio | <u>1.65</u> | <u>1.65</u> |
| Rate of Taper | | |
| Taper Ratio | <u>.129</u> | <u>.129</u> |
| Diehedral Angle, degrees | <u>5°</u> | <u>5°</u> |
| Incidence Angle, degrees | <u>+2°@BODY, 0°@TIP</u> | |
| Aerodynamic Twist, degrees | | |
| Toe-In Angle | | |
| Cant Angle | | |
| Sweep Back Angles, degrees | | |
| Leading Edge | <u>60°</u> | <u>60°</u> |
| Trailing Edge | <u>-8.4°</u> | <u>-8.4°</u> |
| 0.25 Element Line | <u>42.9°</u> | <u>42.9°</u> |
| Chords: | | |
| Root (Wing Sta. 0.0) | <u>104.6 ft.</u> | <u>8.368 in.</u> |
| Tip, (equivalent) | <u>13.5 ft.</u> | <u>1.08 in.</u> |
| MAC | <u>59.0</u> | <u>4.720 in.</u> |
| Fus. Sta. of .25 MAC | | |
| W.P. of .25 MAC | | |
| B.L. of .25 MAC | | |
| Airfoil Section | | |
| Root | | |
| Tip | | |

EXPOSED DATA

| | | |
|----------------------|-----------------------------|------------------------------|
| Area | <u>3217 ft.²</u> | <u>20.59 in.²</u> |
| Span, (equivalent) | <u>69.3 ft.</u> | <u>5.541 in.</u> |
| Aspect Ratio | <u>1.5</u> | <u>1.5</u> |
| Taper Ratio | | |
| Chords | | |
| Root | <u>78.25 ft.</u> | <u>6.26 in.</u> |
| Tip | <u>13.5 ft.</u> | <u>1.08 in.</u> |
| MAC | <u>46.4 ft.</u> | <u>3.712 in.</u> |
| Fus. Sta. of .25 MAC | | |
| W.P. of .25 MAC | | |
| B.L. of .25 MAC | | |

MODEL COMPONENT: V_{TH}

GENERAL DESCRIPTION: THE CENTERLINE MOUNTED VERTICAL TAIL IS SIMULATED FOR HEAT TRANSFER PURPOSES BY A FLAT PLATE 0.200 INCHES THICK WITH A MINIMUM LEADING EDGE RADIUS OF 0.100 INCHES AND A LEADING EDGE SWEEP OF 45°.

DRAWING NUMBER: _____

DIMENSIONS:

| | <u>FULL-SCALE</u> | <u>MODEL SCALE</u> |
|--|----------------------------|-----------------------------|
| Area | <u>805 ft.²</u> | <u>5.15 in.²</u> |
| Span (equivalent) | <u>33.3 ft.</u> | <u>2.664 in.</u> |
| Inb'd equivalent chord | <u>34.6 ft.</u> | <u>2.768 in.</u> |
| Outb'd equivalent chord | <u>13.75 ft.</u> | <u>1.100 in.</u> |
| Ratio Elevator chord/horizontal tail chord | (NO MOVABLE SURFACE) | |
| At Inb'd equiv. chord | <u>-</u> | <u>-</u> |
| At Outb'd equiv. chord | <u>-</u> | <u>-</u> |
| Sweep Back Angles, degrees | | |
| Leading Edge | <u>45°</u> | <u>45°</u> |
| Trailing Edge | <u>19.7°</u> | <u>19.7°</u> |
| Hingeline | <u>-</u> | <u>-</u> |
| Area Moment (Normal to hinge line) | <u>-</u> | <u>-</u> |

MODEL COMPONENT: V_{2H}

GENERAL DESCRIPTION: THE TWIN VERTICAL TAILS ARE SIMULATED FOR HEAT
TRANSFER PURPOSES BY FLAT PLATES OF 0.200 INCH THICKNESS AND 0.100 INCH
LEADING EDGE RADII.

DRAWING NUMBER: _____

| <u>DIMENSIONS:</u> | <u>FULL-SCALE</u> | <u>MODEL SCALE</u> |
|--|----------------------------|------------------------------|
| Area | <u>670 ft.²</u> | <u>4.288 in.²</u> |
| Span (equivalent) | <u>35.5 ft.</u> | <u>2.840 in.</u> |
| Inb'd equivalent chord | <u>33.2 ft.</u> | <u>2.656 in.</u> |
| Outb'd equivalent chord | <u>9.08 ft.</u> | <u>.726 in.</u> |
| Ratio Elevator chord/horizontal tail chord | (NO MOVABLE SURFACE) | |
| At Inb'd equiv. chord | <u>-</u> | <u>-</u> |
| At Outb'd equiv. chord | <u>-</u> | <u>-</u> |
| Sweep Back Angles, degrees | | |
| Leading Edge | <u>40°</u> | <u>40°</u> |
| Tailing Edge | <u>8.5°</u> | <u>8.5°</u> |
| Hingeline | <u>-</u> | <u>-</u> |
| Area Moment (Normal to hinge line) | <u>-</u> | <u>-</u> |

TEST FACILITY DESCRIPTION

Grumman 36-Inch Hypersonic Tunnel

Description: This is an intermittent blowdown to vacuum type tunnel. The test section is 36 inches in diameter. High temperature air from a pebble bed heater is introduced to the test section through fixed contoured, axisymmetric nozzles.

Performance Parameters:

| | |
|--|--------------|
| Mach Range: | 8, 10, 14 |
| Reynold's Number ($\times 10^6/\text{ft}$): | 0.2 to 4.5 |
| Stagnation Pressure (psia): | 200 to 2200 |
| Dynamic Pressure (psf): | 100 to 1200 |
| Stagnation Temperature ($^{\circ}\text{R}$): | 1000 to 3500 |
| Run Time (sec): | 30 to 60 |

Testing Capabilities: Model mounting consists of a water-cooled, sting balance sector rig which features a model injection system. Instrumentation for force, pressure, and heat transfer measurement is provided. A Schlieren System is available.

PHASE CHANGE PAINT DATA

The test results are shown in Figures 4 through 50 in the form of heating contours. These contours are correlated to heat transfer coefficient ratios (h/h_o), the ratios of local heat transfer coefficients on the model surface to the heat transfer coefficient at the stagnation point of a 1/150 foot radius sphere. The grid systems shown in Photographs 1 and 2 were permanently marked on each test model. The grid lines were positioned in a projected planform view one inch apart parallel to fuselage stations (from F.S. 200) and one half inch apart parallel to butt lines (from model centerline). The vertical tail grid lines are one half inch apart in a projected profile view parallel to water lines.

LIST OF NOMENCLATURE

- h Heat transfer coefficient based on temperature (BTU/SEC-ft²-°R)
- h_o Heat transfer coefficient at the stagnation point of a 1 foot radius sphere at model scale
- RN Reynold's Number (non-dimensional)
- α Angle of attack (degrees)
- β Angle of sideslip (Degrees)
- ϕ Angle of roll (Degrees)

TABLE 1

PHASE CHANGE COATING TEST DATA SUMMARY SHEET

TEST TITLE: SPACE SHUTTLE ORBITER HEAT TRANSFER MODEL TEST
 TEST NUMBER: GFHT-017 TEST FACILITY: GAC HYPERSONIC TUNNEL
 TEST DATE: FEBRUARY 20- MARCH 22, 1974 TEST ENGINEER: A. D'ERRICO

| Run No. | Model Configuration Identification | Model Scale | Free Stream Mach Number | Total Pressure (psia) | Total Temp. (°R) | T _{aw} * / T _{total} | RNX10 ⁶ Ft | Phase Change Temp. (°F) | Model Position (degrees) | | | h _{r=1'} | T _w ** | |
|---------|--|-------------|-------------------------|-----------------------|------------------|--|-----------------------|-------------------------|--------------------------|---|-----|-------------------|-------------------|-------|
| | | | | | | | | | α | β | φ | | | |
| 2 | B ₁ ^W V _{1H} 1H | .0067 | 8.0 | 123.0 | 1417 | 1.0 | .47 | 200 | 0 | 0 | 0 | .0301 | 535°R | |
| 5 | | | | 123.2 | 1272 | | .57 | 200 | 20 | | | .0297 | | |
| 6 | | | | 124.8 | 1405 | | .48 | 113 | 20 | | | .0303 | | |
| 7 | | | | 123.6 | 1495 | | .43 | 200 | 30 | | | .0304 | | |
| 8 | | | | 123.1 | 1259 | | .58 | 113 | 30 | | | .0297 | | |
| 9 | | | | 125.9 | 1443 | | .47 | 113 | 0 | | | .0306 | | |
| 11 | | | | 121.4 | 1435 | | .45 | 113 | 0 | | 180 | .0300 | | |
| 14 | | | | 123.7 | 1314 | | .54 | 113 | 20 | | | .0299 | | |
| 18 | | | | 231.7 | 1560 | | .75 | 113 | 30 | | | .0420 | | |
| 19 | | | | 237.5 | 1625 | | .72 | 200 | 50 | | 0 | .0427 | | |
| 20 | | | | 234.3 | 1617 | | .71 | 113 | 50 | | | .0424 | | |
| 21 | | | | 227.9 | 1552 | | .74 | 113 | 50 | | 180 | .0416 | | |
| 22 | B ₂ ^W V _{2H} 2H | | | 240.1 | 1604 | | .74 | 350 | 50 | | 0 | .0429 | | 535°R |

** T_w = wall temperature assumed in h_{r=1'} calculation

* T_{aw} = adiabatic wall temperature

TABLE 2

PHASE CHANGE COATING TEST DATA SUMMARY SHEET

TEST TITLE: SPACE SHUTTLE ORBITER HEAT TRANSFER MODEL TEST

TEST NUMBER: GHFT-017 TEST FACILITY: GAC HYPERSONIC TUNNEL

TEST DATE: FEBRUARY 20-MARCH 22, 1971 TEST ENGINEER: A. D'Errico

| Run No. | Model Configuration Identification | Model Scale | Free Stream Mach Number | Total Pressure (psia) | Total Temp. (°R) | T _{aw} * / T _{total} | RNX10 ⁶ Ft | Phase Change Temp. (°F) | Model Position (degrees) | | | h _{r=1'} | T _w ** | |
|---------|--|-------------|-------------------------|-----------------------|------------------|--|-----------------------|-------------------------|--------------------------|---|-----|-------------------|-------------------|-------|
| | | | | | | | | | α | β | φ | | | |
| 23 | B ₂ W _{1H} V _{2H} | .0067 | 8.0 | 240.0 | 1560 | 1.0 | .78 | 200 | 50 | 0 | 180 | .0427 | 535°R | |
| 24 | | | | 241.6 | 1606 | | .74 | 113 | 50 | | | .0430 | | |
| 26 | | | | 238.9 | 1614 | | .73 | 113 | 30 | | | .0428 | | |
| 28 | | | | 244.0 | 1531 | | .82 | 113 | 20 | | | .0430 | | |
| 29 | | | | 240.9 | 1579 | | .76 | 200 | 20 | | | .0429 | | |
| 30 | | | | 242.9 | 1615 | | .74 | 200 | 0 | | | .0431 | | |
| 31 | | | | 243.8 | 1707 | | .67 | 113 | 0 | | | .0435 | | |
| 32 | B ₁ W _{1H} V _{1H} | | | 536.9 | 1525 | | 1.82 | 113 | 20 | | | .0641 | | |
| 66 | B ₁ W _{1H} V _{1H} U _{1H} | | | 239.4 | 1536 | | .80 | 113 | 20 | | 0 | .0426 | | |
| 67 | | | | 239.5 | 1496 | | .84 | 200 | 20 | | 0 | .0424 | | |
| 68 | | | | 243.1 | 1418 | | .93 | 200 | 0 | | 0 | .0425 | | |
| 69 | | | | 239.0 | 1299 | | 1.06 | 113 | 0 | | 0 | .0416 | | |
| 70 | | | | 242.1 | 1452 | | .89 | 113 | 50 | | 0 | .0425 | | 535°R |

** T_w = wall temperature assumed in h_{r=1'} calculation

* T_{aw} = adiabatic wall temperature

TABLE 3

PHASE CHANGE COATING TEST DATA SUMMARY SHEET

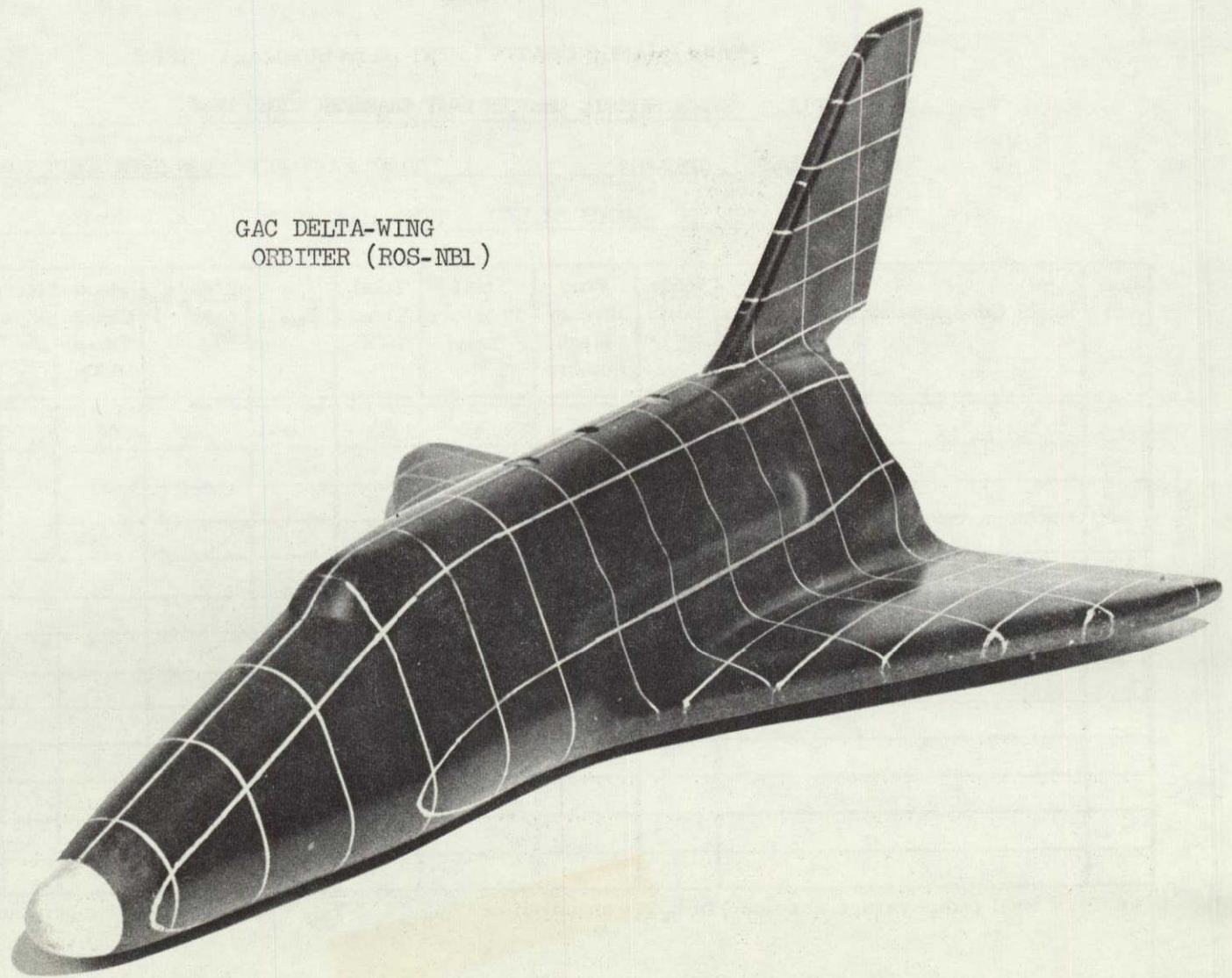
TEST TITLE: SPACE SHUTTLE ORBITER HEAT TRANSFER MODEL TEST
 TEST NUMBER: GHFT-017 TEST FACILITY: GAC HYPERSONIC TUNNEL
 TEST DATE: FEB. 20 - MARCH 22, 1971 TEST ENGINEER: A. D'Errico

| Run No. | Model Configuration Identification | Model Scale | Free Stream Mach Number | Total Pressure (psia) | Total Temp. (°R) | $\frac{T_{aw}^*}{T_{total}}$ | $\frac{RNX10^6}{Ft}$ | Phase Change Temp. (°F) | Model Position (degrees) | | | $h_{r=1'}$ | T_w^{**} |
|---------|---|-------------|-------------------------|-----------------------|------------------|------------------------------|----------------------|-------------------------|--------------------------|---------|--------|------------|------------|
| | | | | | | | | | α | β | ϕ | | |
| 71 | B ^W V ^U 1 1H 1H 1H | .0067 | 8.0 | 244.4 | 1382 | 1.0 | .98 | 200 | 50 | 0 | 0 | .0425 | 535°R |
| | | | | | | | | | | | | | |
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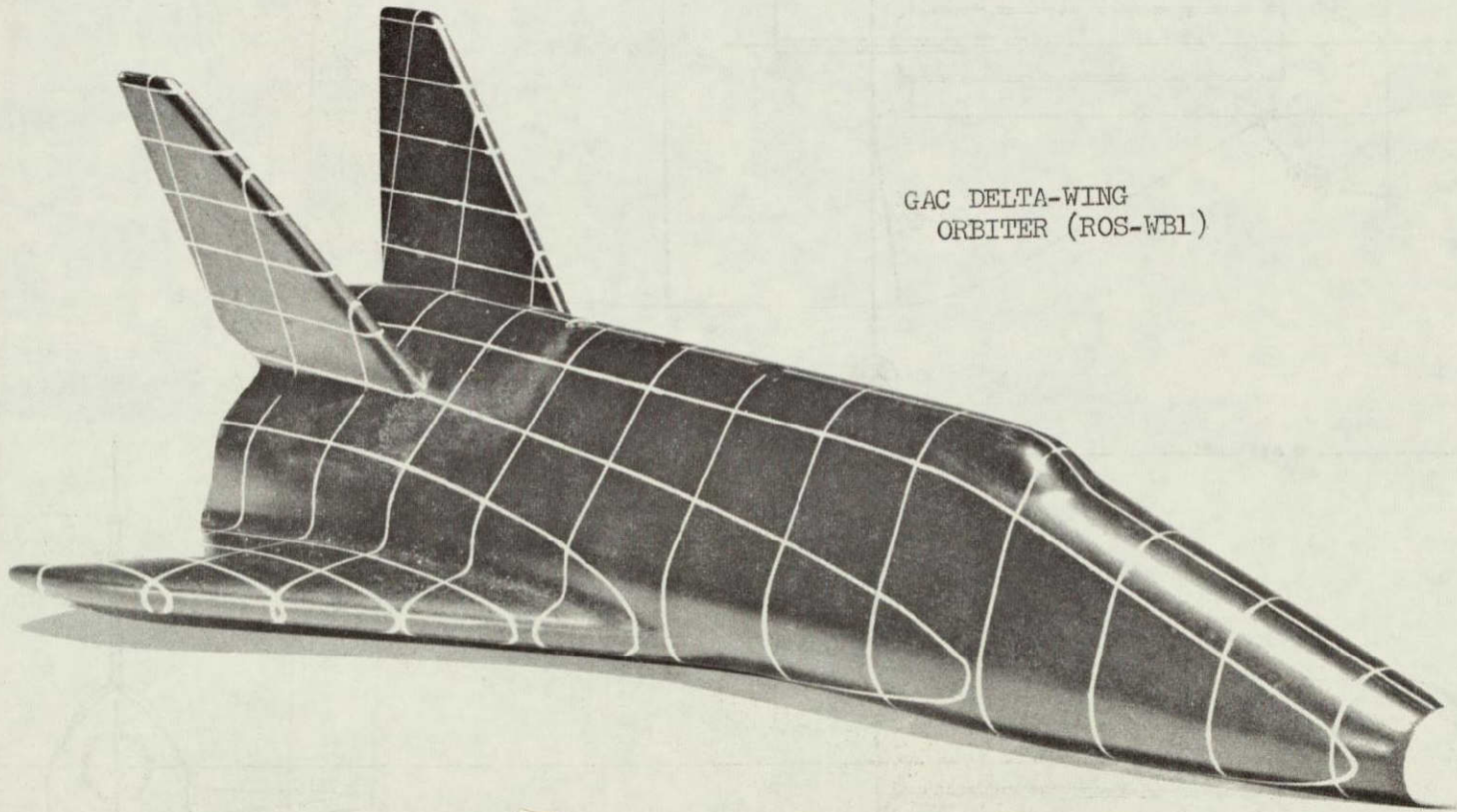
PAGE 13

** T_w = wall temperature assumed in $h_{r=1'}$ calculation * T_{aw} = adiabatic wall temperature

GAC DELTA-WING
ORBITER (ROS-NBL)



GAC DELTA-WING
ORBITER (ROS-WBL)



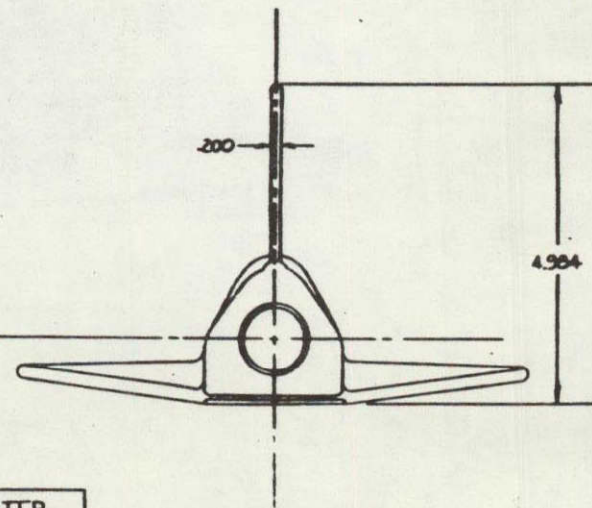
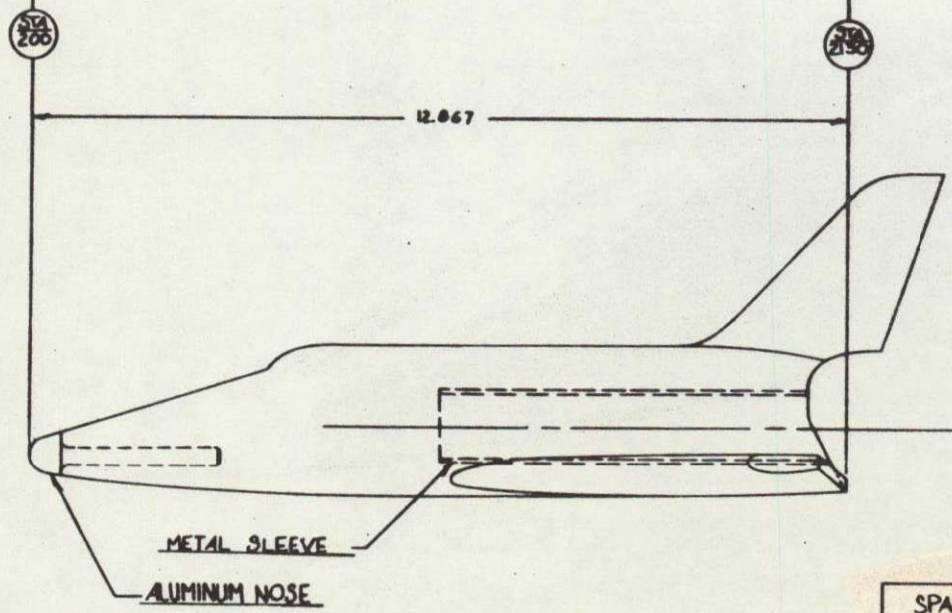
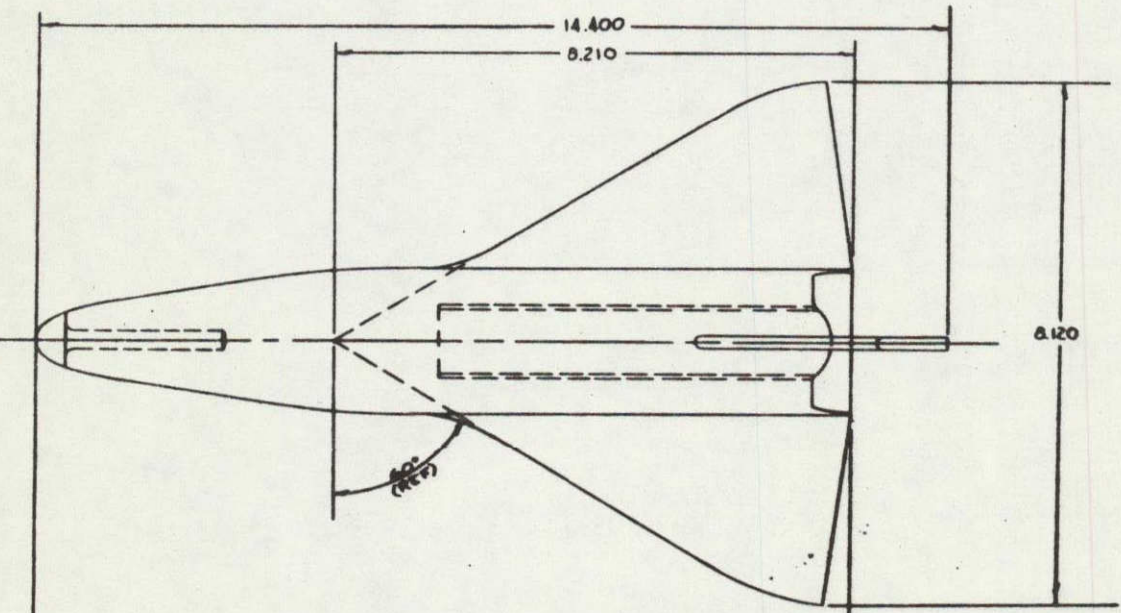
NOT REPRODUCIBLE



FIGURE 1



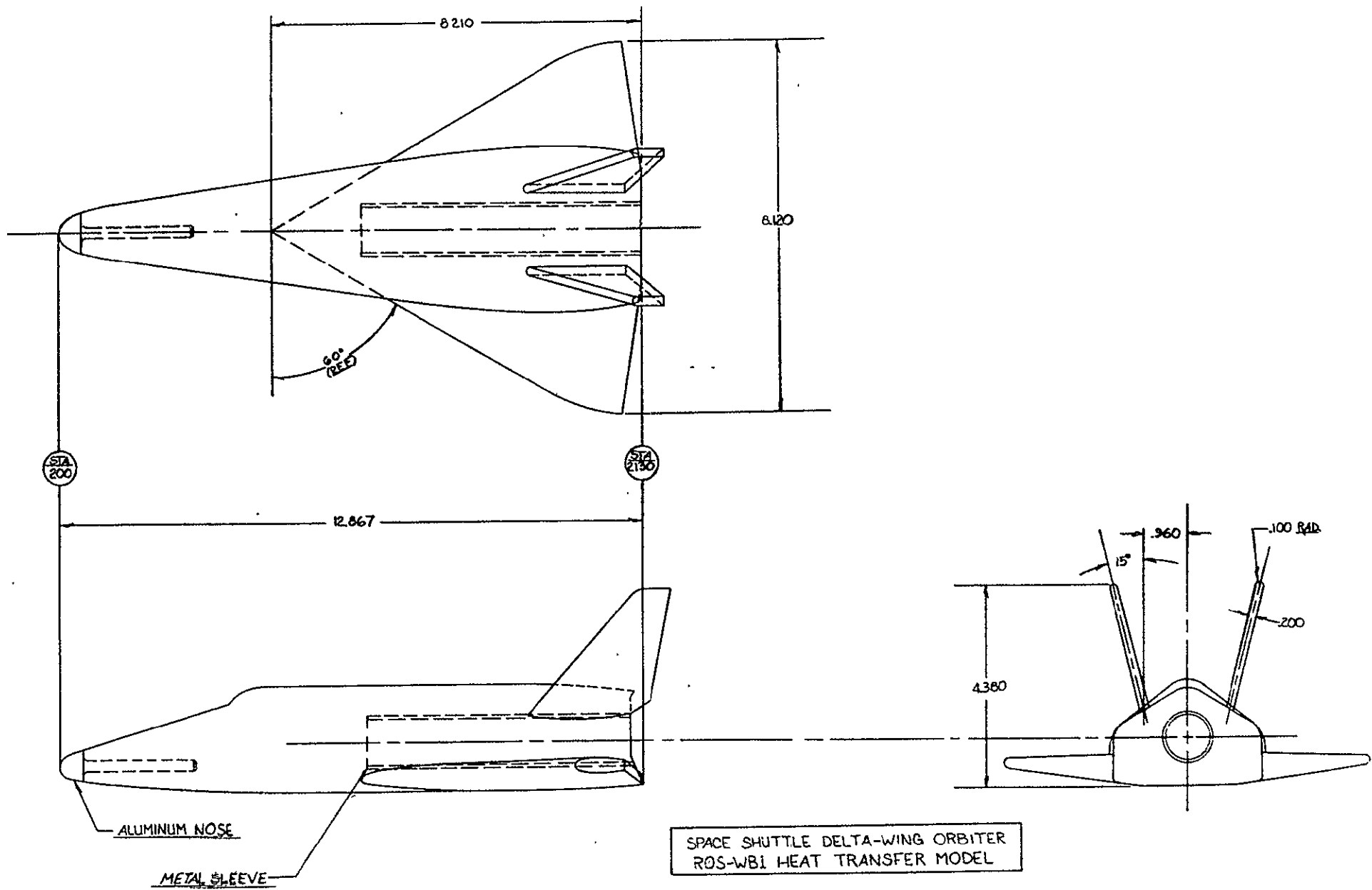
PAGE 16



SPACE SHUTTLE DELTA-WING ORBITER ROS-NBI HEAT TRANSFER MODEL

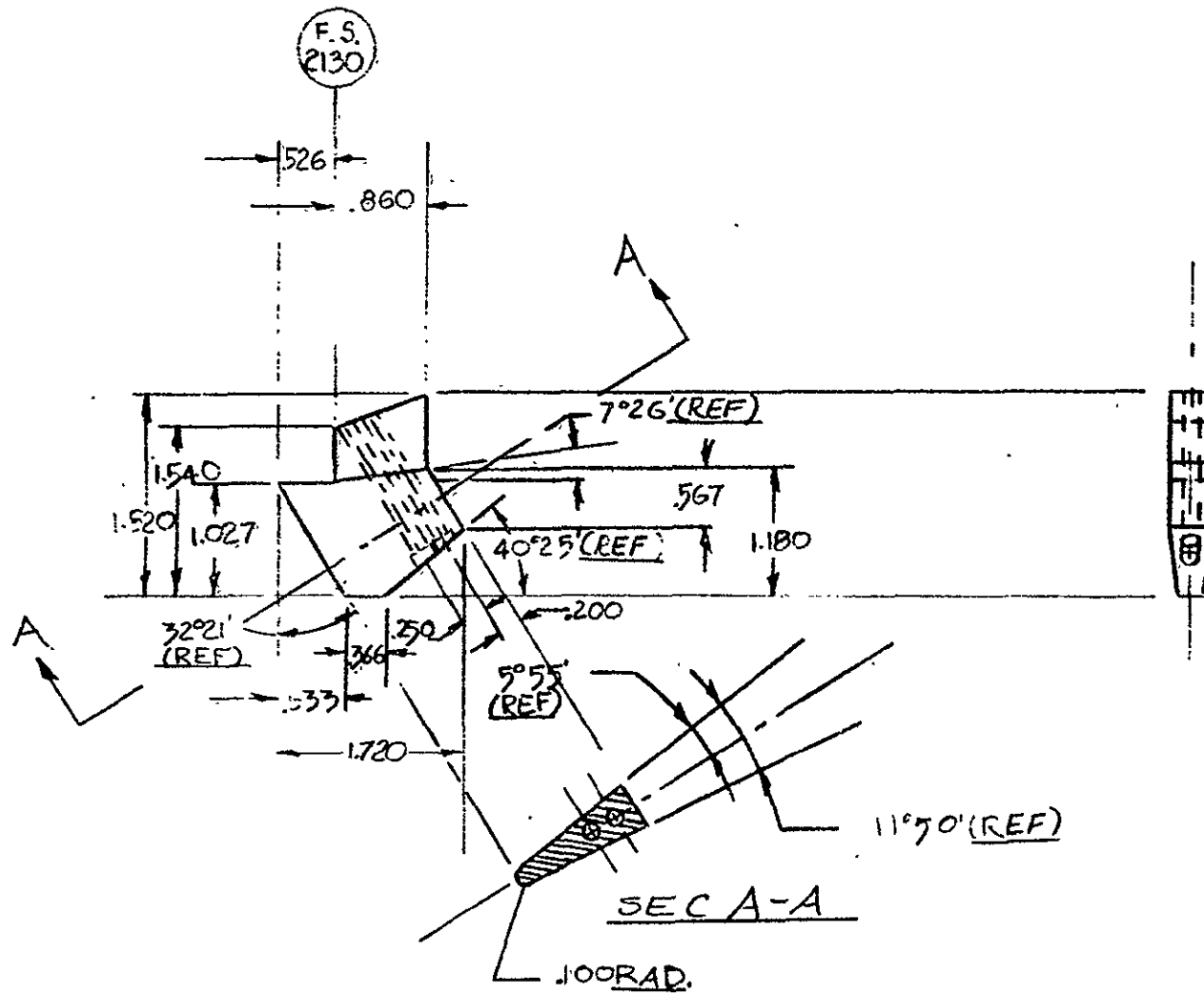
FIGURE 2

PAGE 17



SPACE SHUTTLE DELTA-WING ORBITER
ROS-WBI HEAT TRANSFER MODEL

FIGURE 3



PAGE 18

VENTRAL FIN [UM]

1/150 SCALE HEAT
TRANSFER MODEL

SUMMARY OF HEATING CONTOURS

| | <u>PAGE</u> |
|-------------------------------------|-------------|
| I. ROS-NBL, WINDWARD | |
| A. $\alpha = 0$, Run 002 | 22 |
| B. $\alpha = 0$, Run 009 | 23 |
| C. $\alpha = 20$, Run 005 | 24 |
| D. $\alpha = 20$, Run 006 | 25 |
| E. $\alpha = 30$, Run 007 | 26 |
| F. $\alpha = 30$, Run 008 | 27 |
| G. $\alpha = 50$, Run 019 | 28 |
| II. ROS-WBL, WINDWARD | |
| A. $\alpha = 50$, Run 022 | 29 |
| III. ROS-NBL, VENTRAL FIN, WINDWARD | |
| A. $\alpha = 0$, Run 068 | 30 |
| B. $\alpha = 0$, Run 069 | 31 |
| C. $\alpha = 20$, Run 067 | 32 |
| D. $\alpha = 50$, Run 071 | 33 |
| IV. ROS-NBL, VENTRAL FIN, PROFILE | |
| A. $\alpha = 0$, Run 068 | 34 |
| B. $\alpha = 0$, Run 069 | 35 |
| C. $\alpha = 20$, Run 067 | 36 |
| D. $\alpha = 50$, Run 071 | 37 |
| V. ROS-NBL, LEESIDE | |
| A. $\alpha = 0$, Run 011 | 38 |
| B. $\alpha = 20$, Run 014 | 39 |
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| D. $\alpha = 30$, Run 018 | 41 |
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SUMMARY OF HEATING CONTOURS (Continued)

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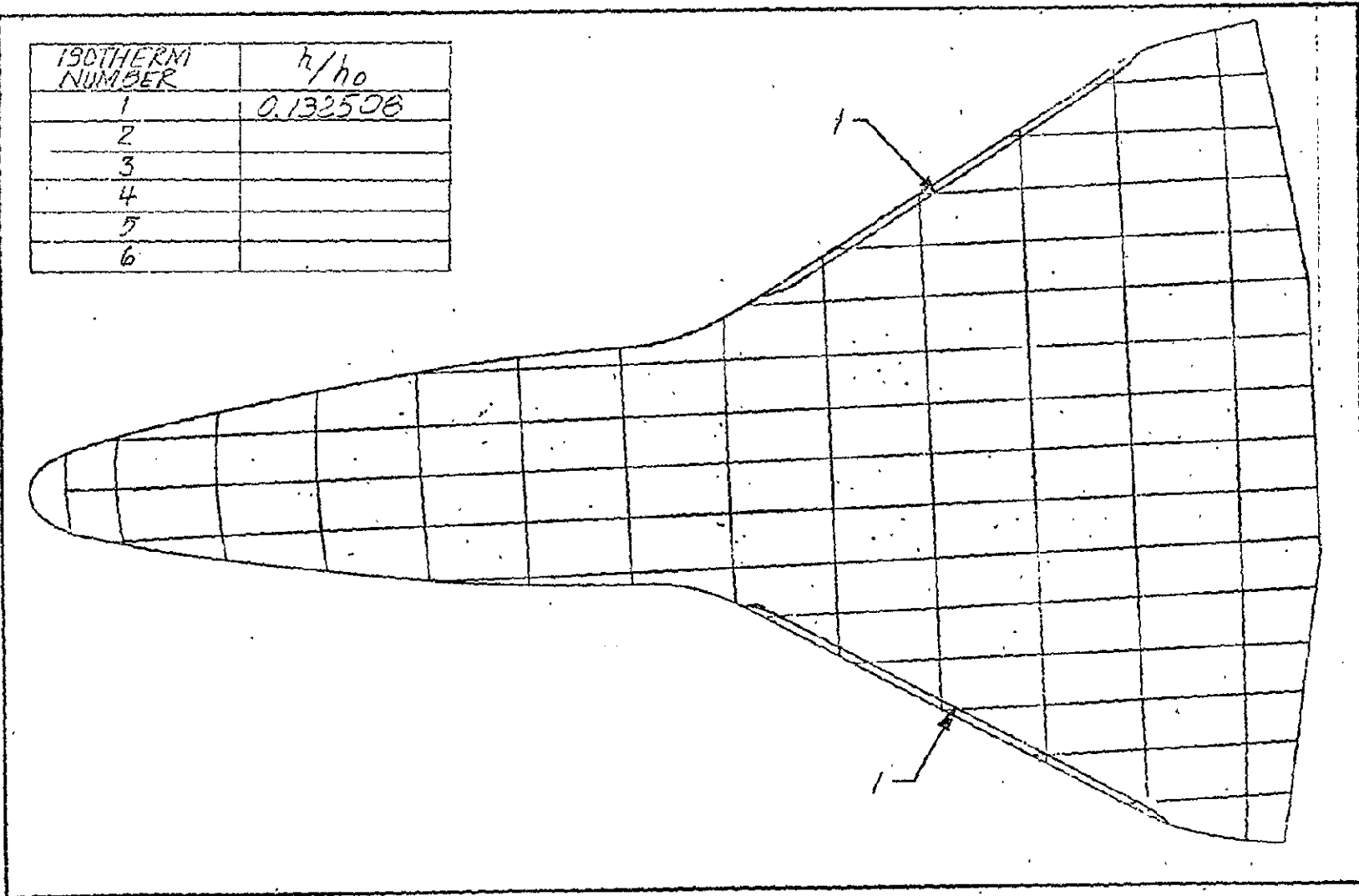
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PHASE CHANGE COATING TEST RUN SHEET

TEST NUMBER: GFHT--017 TEST RUN NUMBER: 002

| ISOTHERM NUMBER | h/h_0 |
|-----------------|----------|
| 1 | 0.132506 |
| 2 | |
| 3 | |
| 4 | |
| 5 | |
| 6 | |

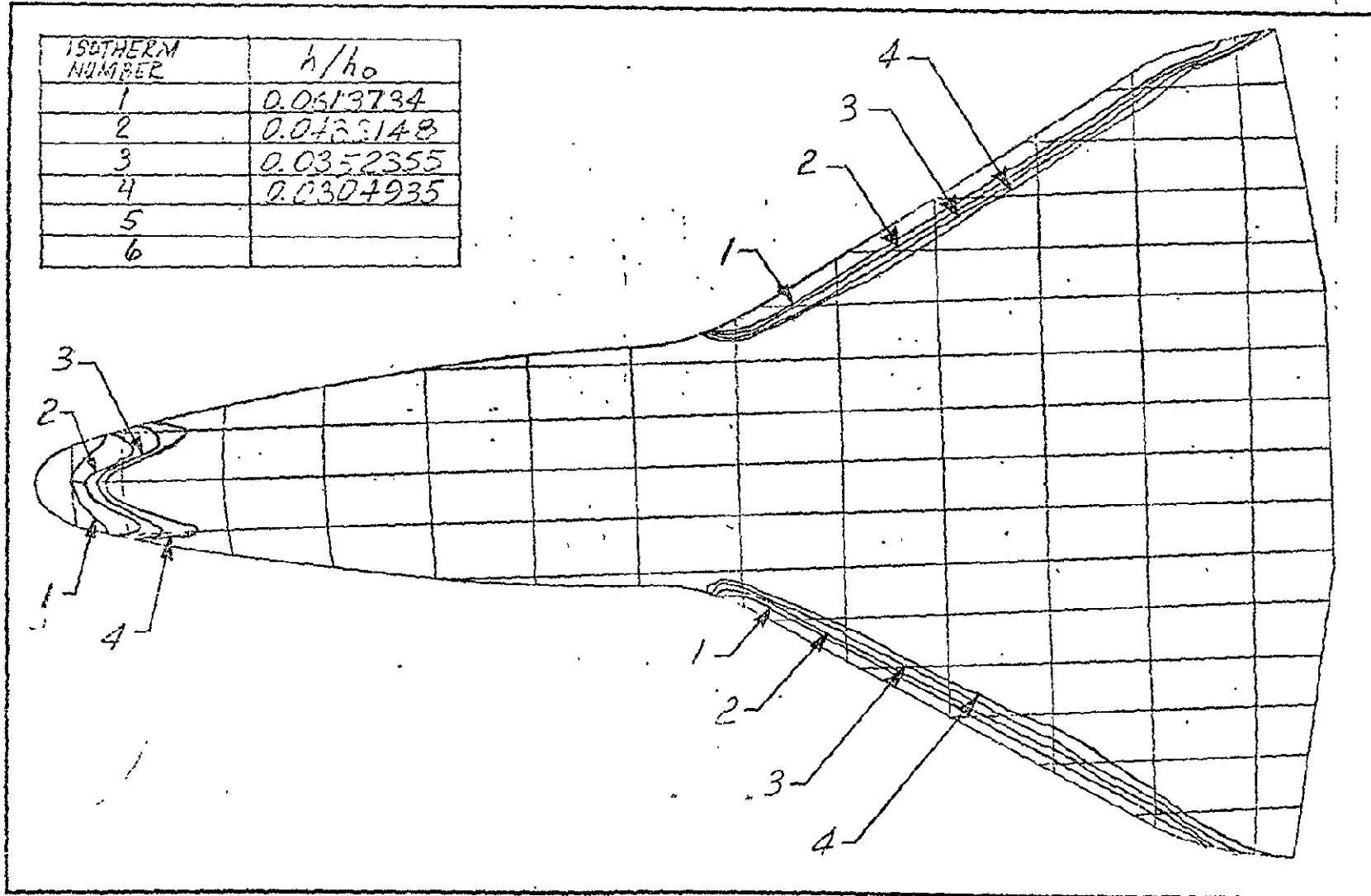
2



PHASE CHANGE COATING TEST RUN SHEET

TEST NUMBER: GFHT-017 TEST RUN NUMBER: 009

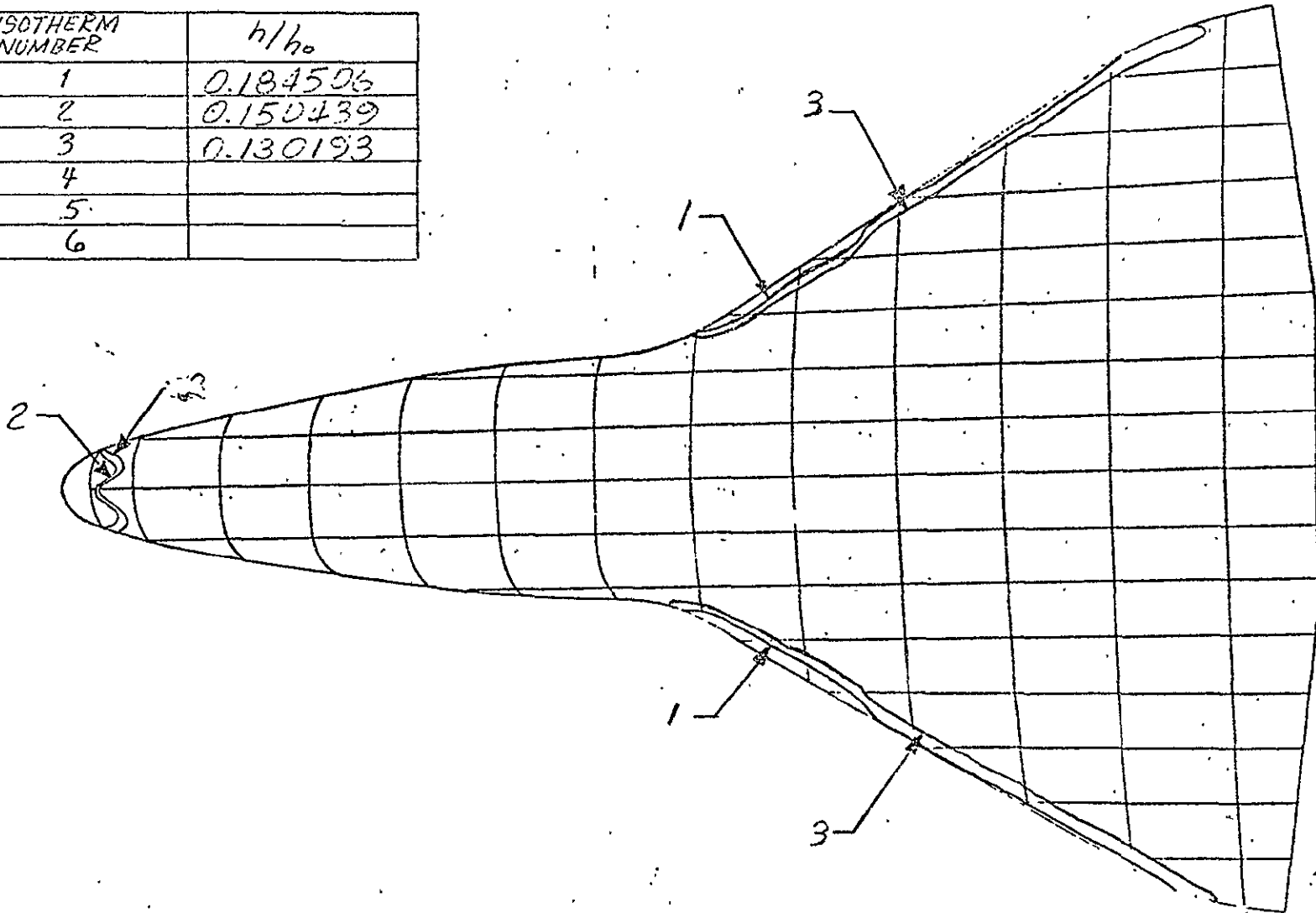
| ISOTHERM NUMBER | h/h_0 |
|-----------------|-----------|
| 1 | 0.0613734 |
| 2 | 0.0465148 |
| 3 | 0.0352355 |
| 4 | 0.0304935 |
| 5 | |
| 6 | |



PHASE CHANGE COATING TEST RUN SHEET

TEST NUMBER: GFHT-017 TEST RUN NUMBER: 005

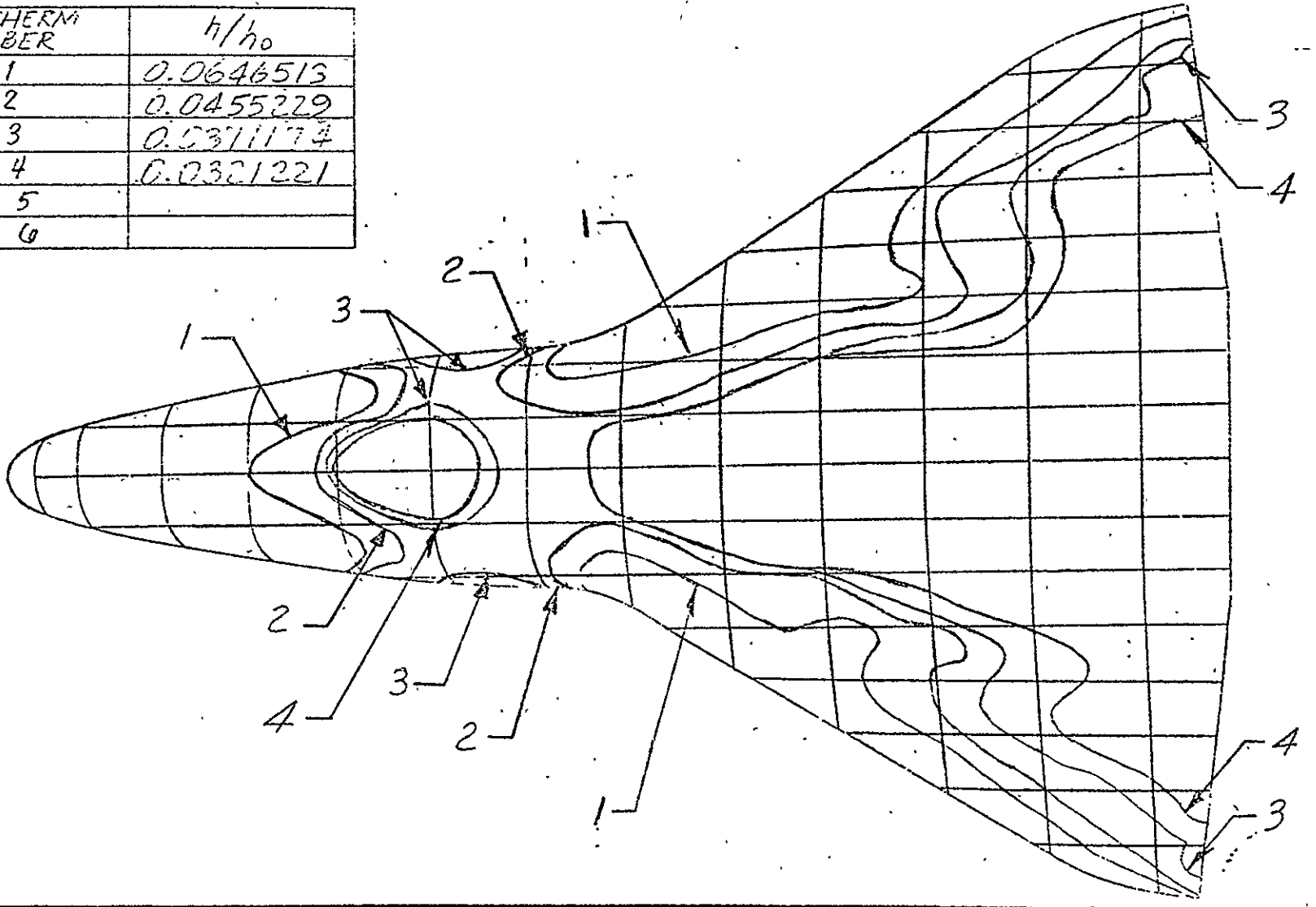
| ISOTHERM NUMBER | h/h_0 |
|-----------------|----------|
| 1 | 0.184506 |
| 2 | 0.150439 |
| 3 | 0.130193 |
| 4 | |
| 5 | |
| 6 | |



PHASE CHANGE COATING TEST RUN SHEET

TEST NUMBER: GFHT-017 TEST RUN NUMBER: 006

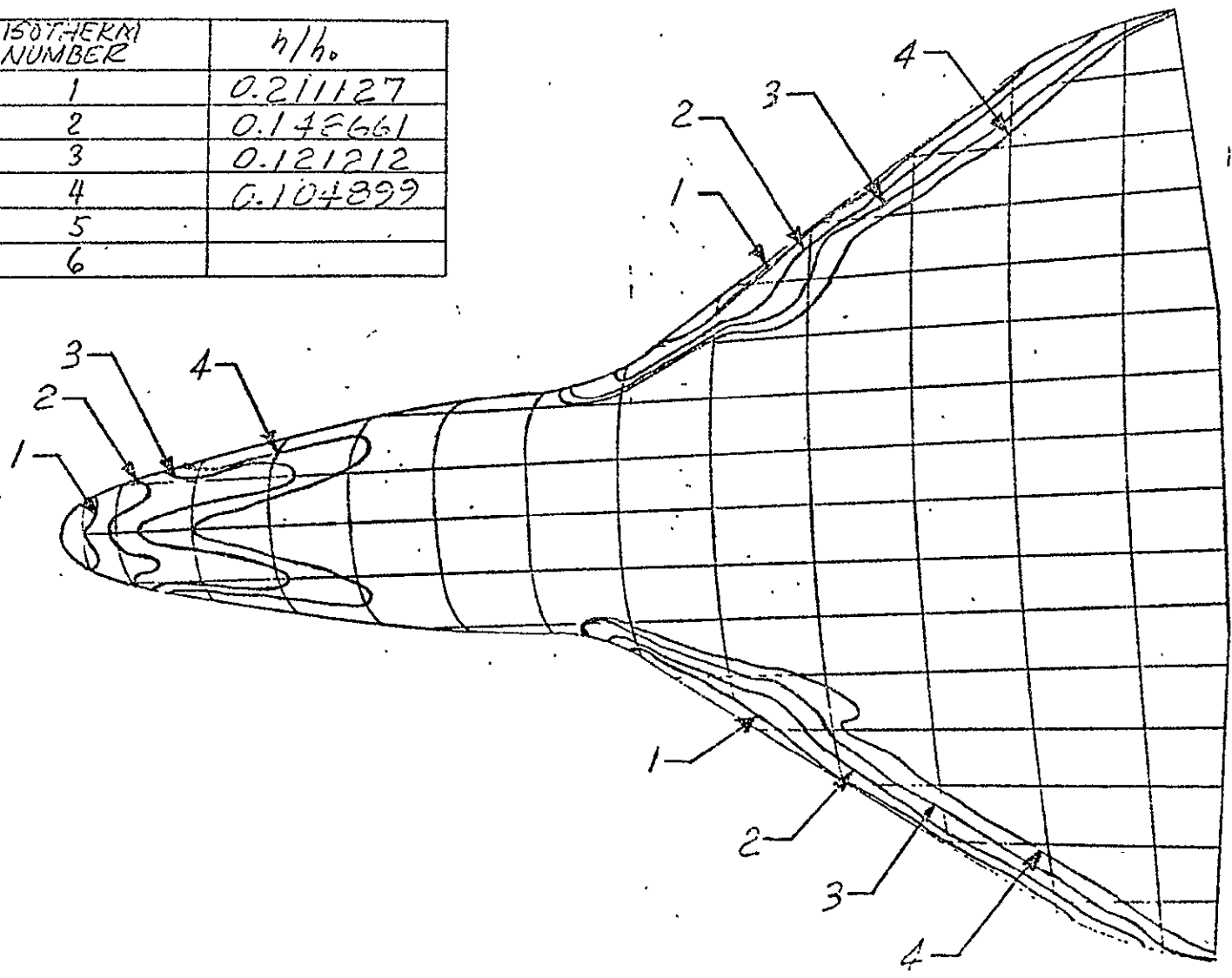
| ISOTHERM NUMBER | t_i/h_0 |
|-----------------|-----------|
| 1 | 0.0646513 |
| 2 | 0.0455229 |
| 3 | 0.5371174 |
| 4 | 0.0321221 |
| 5 | |
| 6 | |



PHASE CHANGE COATING TEST RUN SHEET

TEST NUMBER: GFHT-017 TEST RUN NUMBER: 007

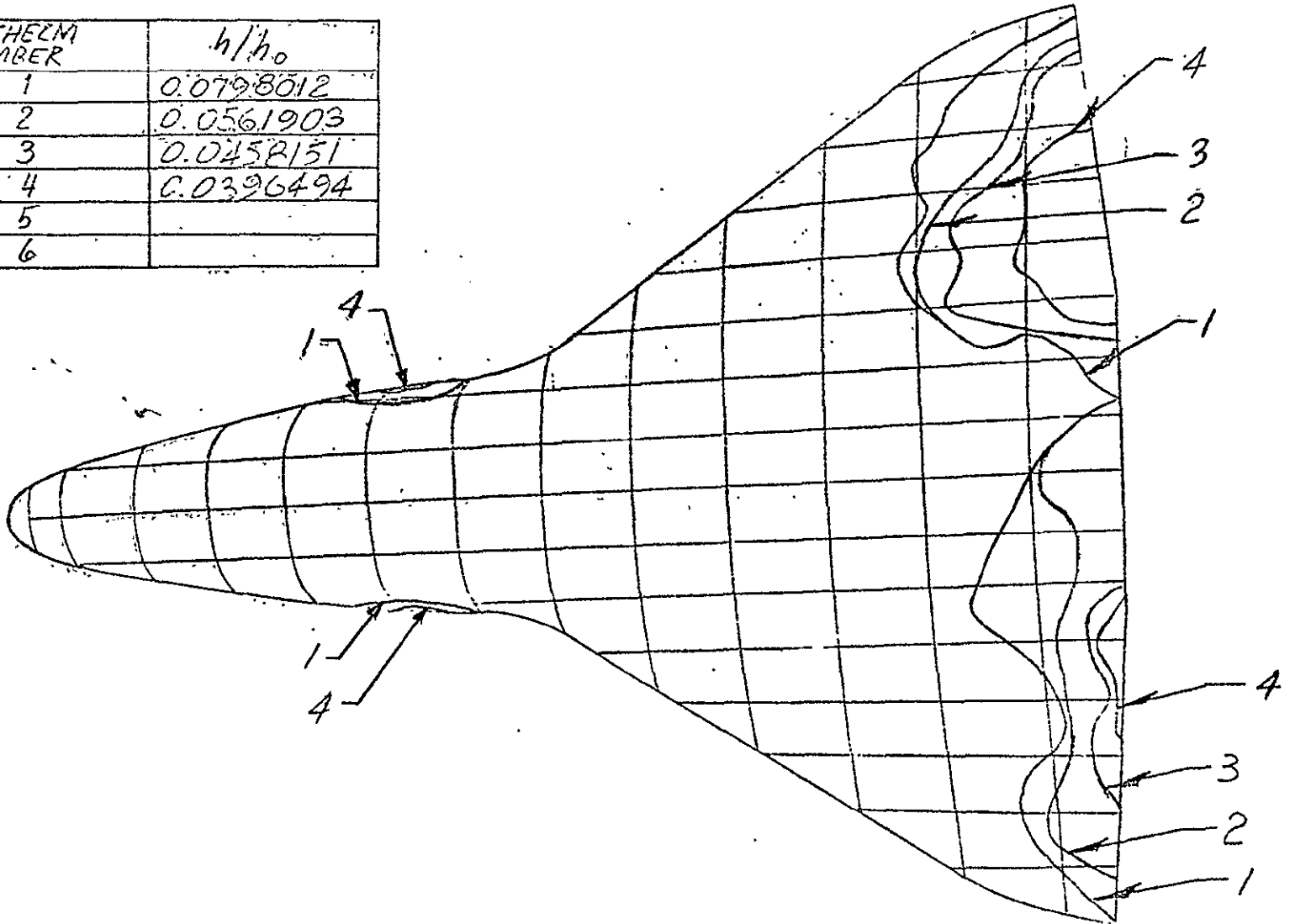
| ISOTHERM NUMBER | h/h_0 |
|-----------------|----------|
| 1 | 0.211127 |
| 2 | 0.148661 |
| 3 | 0.121212 |
| 4 | 0.104899 |
| 5 | |
| 6 | |



PHASE CHANGE COATING TEST RUN SHEET

TEST NUMBER: SEHT-017 TEST RUN NUMBER: 008

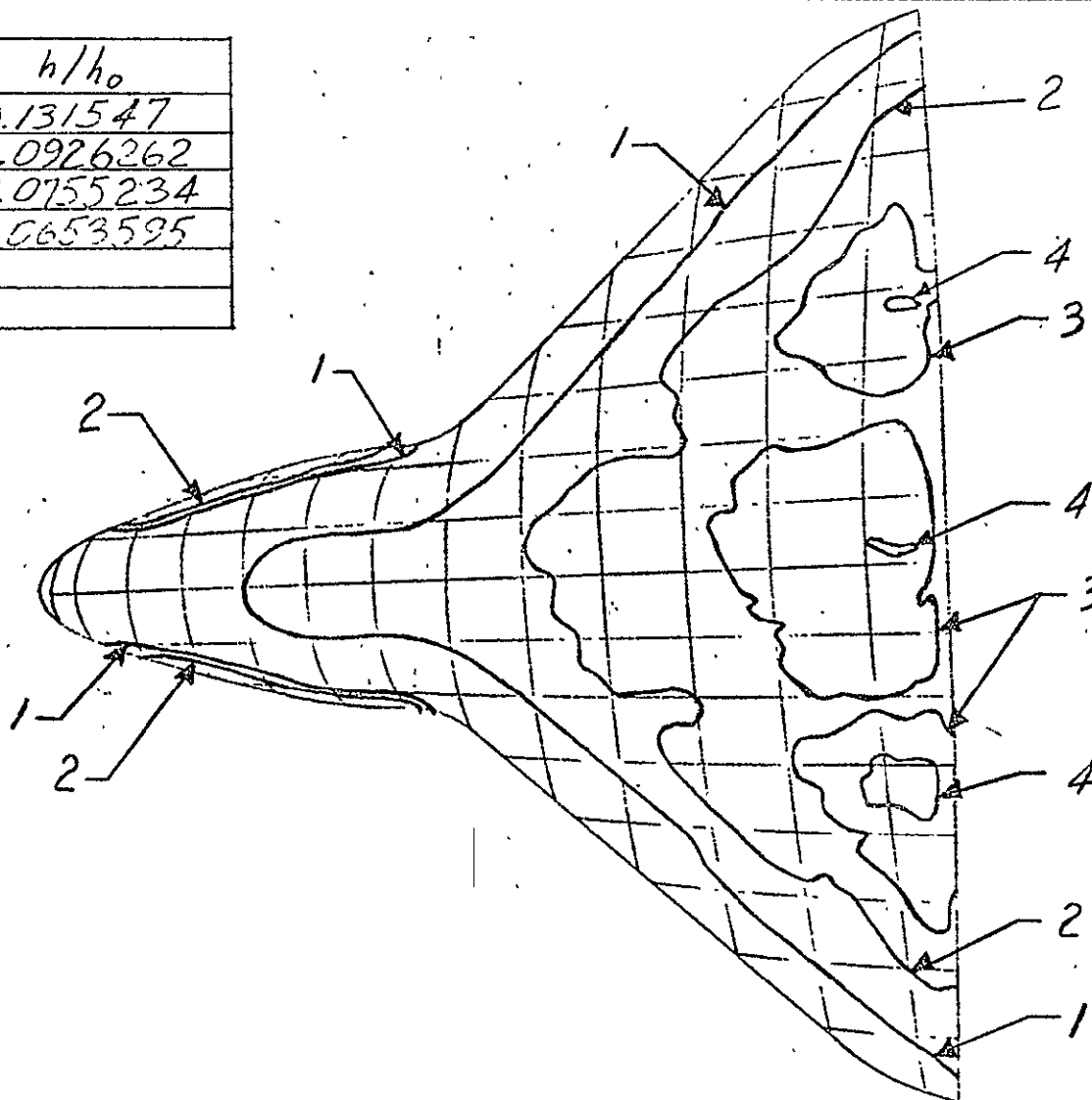
| ISOTHERM NUMBER | h/h_0 |
|-----------------|-----------|
| 1 | 0.0798012 |
| 2 | 0.0561903 |
| 3 | 0.0458151 |
| 4 | 0.0326494 |
| 5 | |
| 6 | |



PHASE CHANGE COATING TEST RUN SHEET

TEST NUMBER: GFHT-017 TEST RUN NUMBER: 019

| ISOTHERM NUMBER | h/h_0 |
|-----------------|-----------|
| 1 | 0.131547 |
| 2 | 0.0926262 |
| 3 | 0.0755234 |
| 4 | 0.0653595 |
| 5 | |
| 6 | |

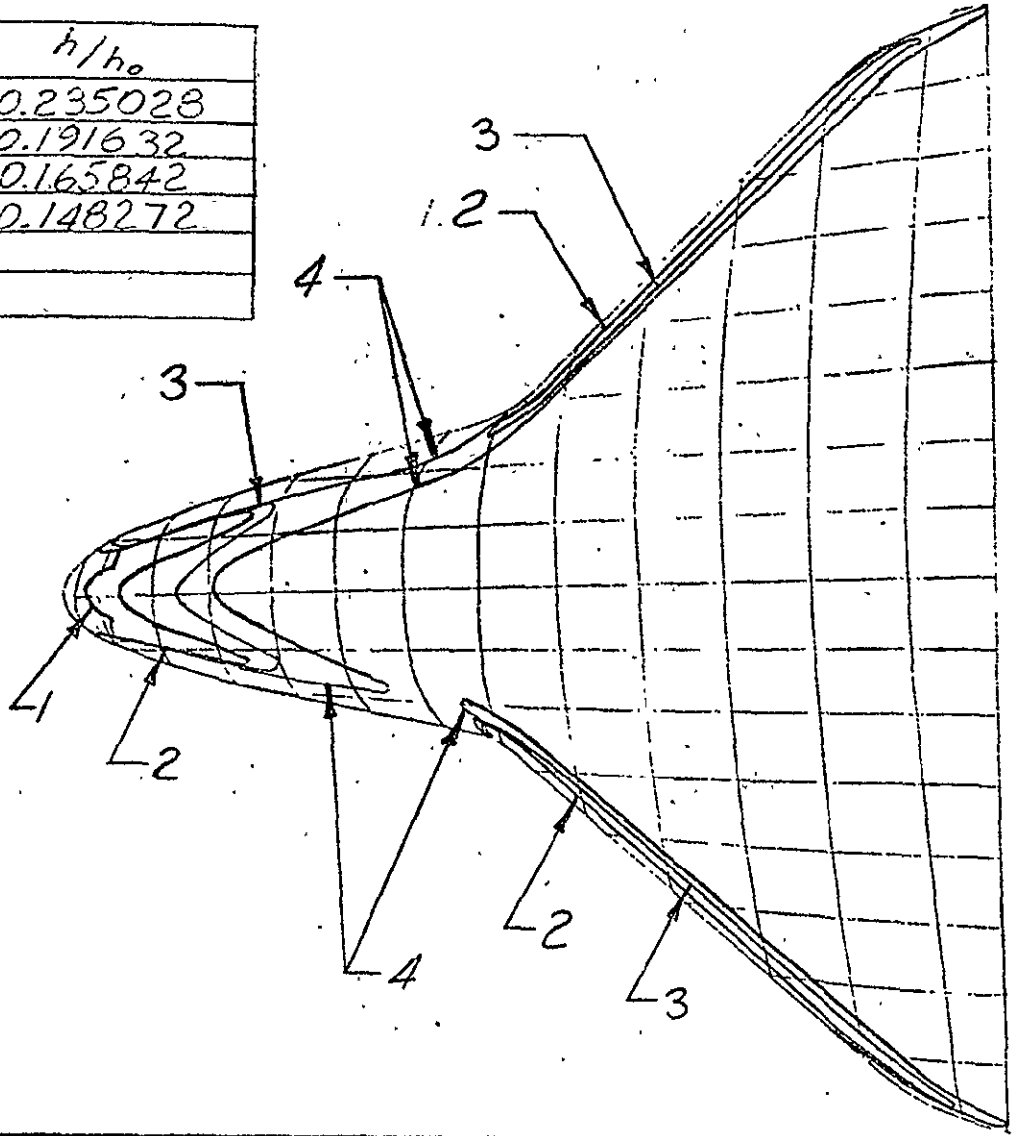


PHASE CHANGE COATING TEST RUN SHEET

TEST NUMBER: GFHT-017

TEST RUN NUMBER: 022

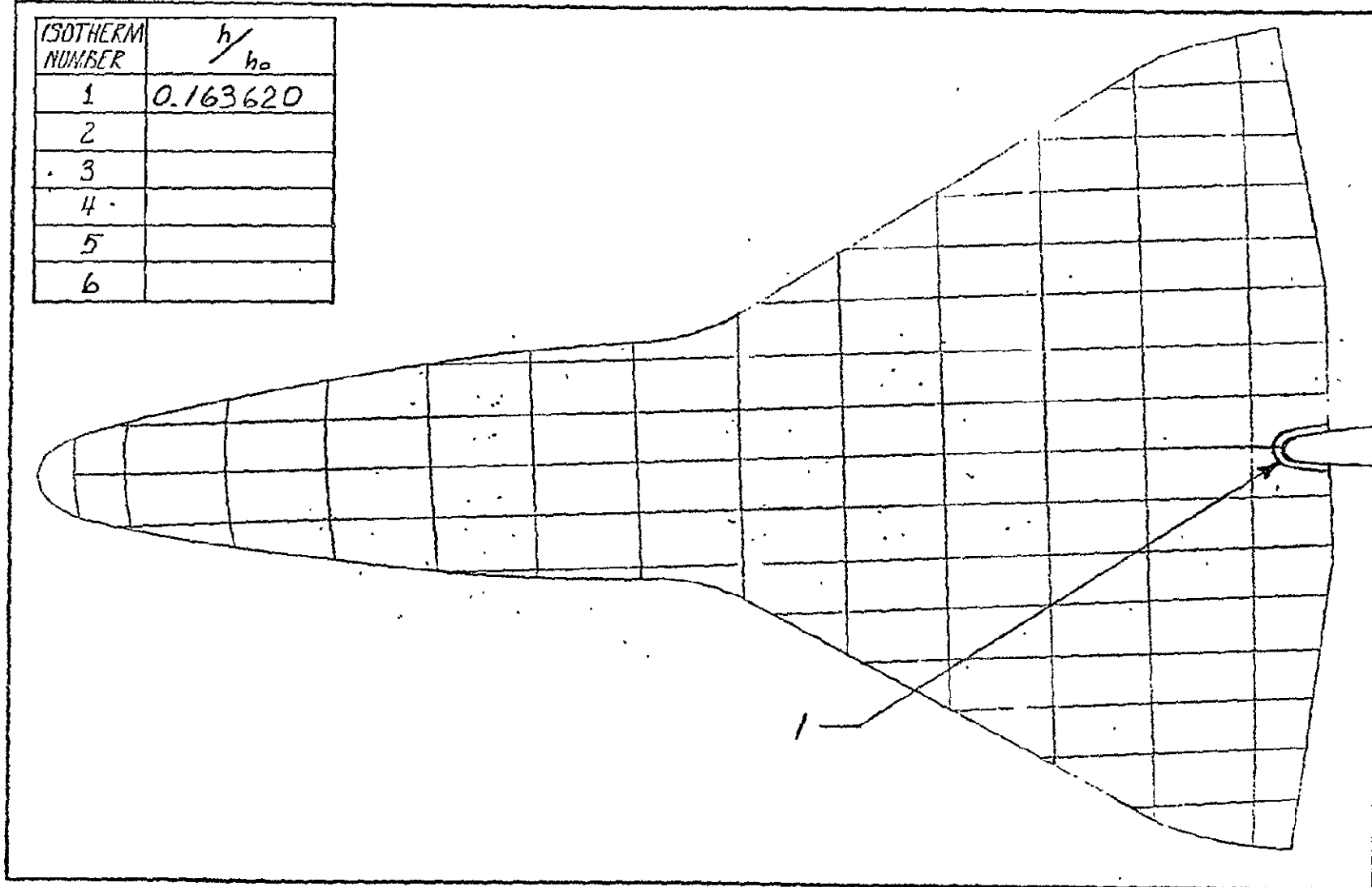
| ISOTHERM NUMBER | h/h_0 |
|-----------------|----------|
| 1 | 0.235028 |
| 2 | 0.191632 |
| 3 | 0.165842 |
| 4 | 0.148272 |
| 5 | |
| 6 | |



PHASE CHANGE COATING TEST RUN SHEET

TEST NUMBER: GFHT-017 TEST RUN NUMBER: 068

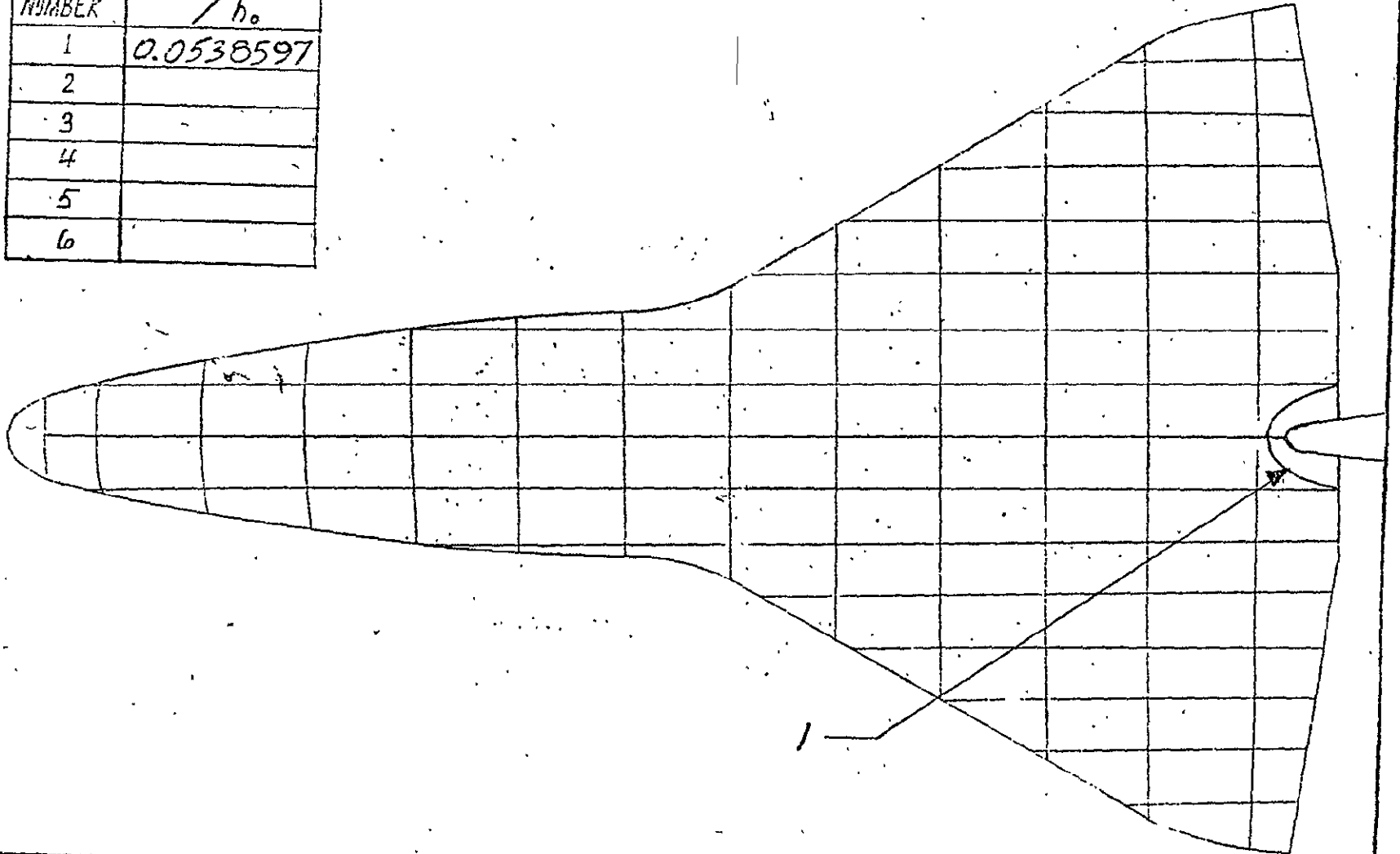
| ISOTHERM NUMBER | h/h_0 |
|-----------------|----------|
| 1 | 0.163620 |
| 2 | |
| 3 | |
| 4 | |
| 5 | |
| 6 | |



PHASE CHANGE COATING TEST RUN SHEET

TEST TEST TEST NUMBER: GFHT-017 TEST RUN NUMBER: 069

| ISOTHERM NUMBER | h/h_0 |
|-----------------|-----------|
| 1 | 0.0538597 |
| 2 | |
| 3 | |
| 4 | |
| 5 | |
| 6 | |

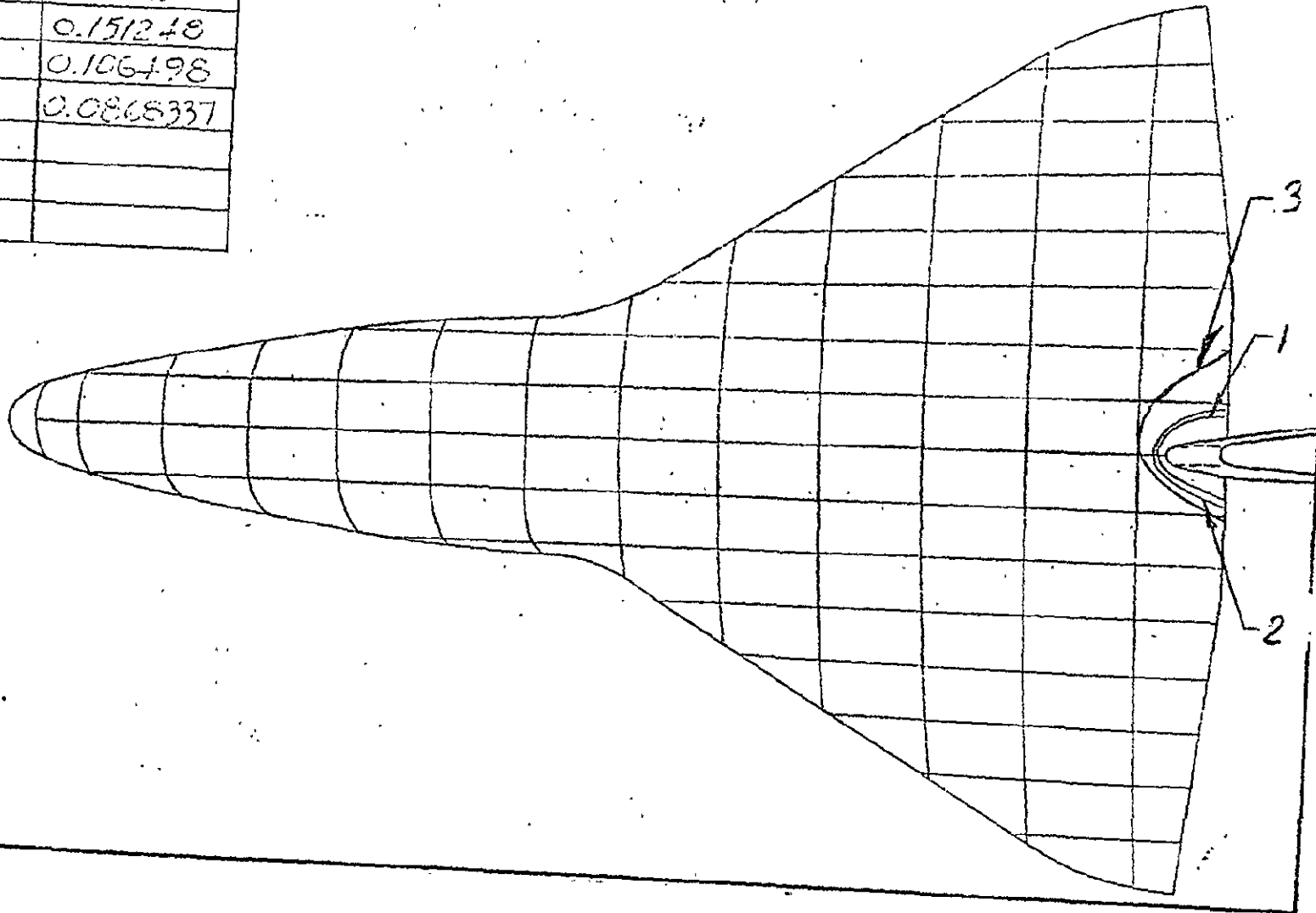


PHASE CHANGE COATING TEST RUN SHEET

TEST NUMBER: GEHT-017

TEST RUN NUMBER: 067

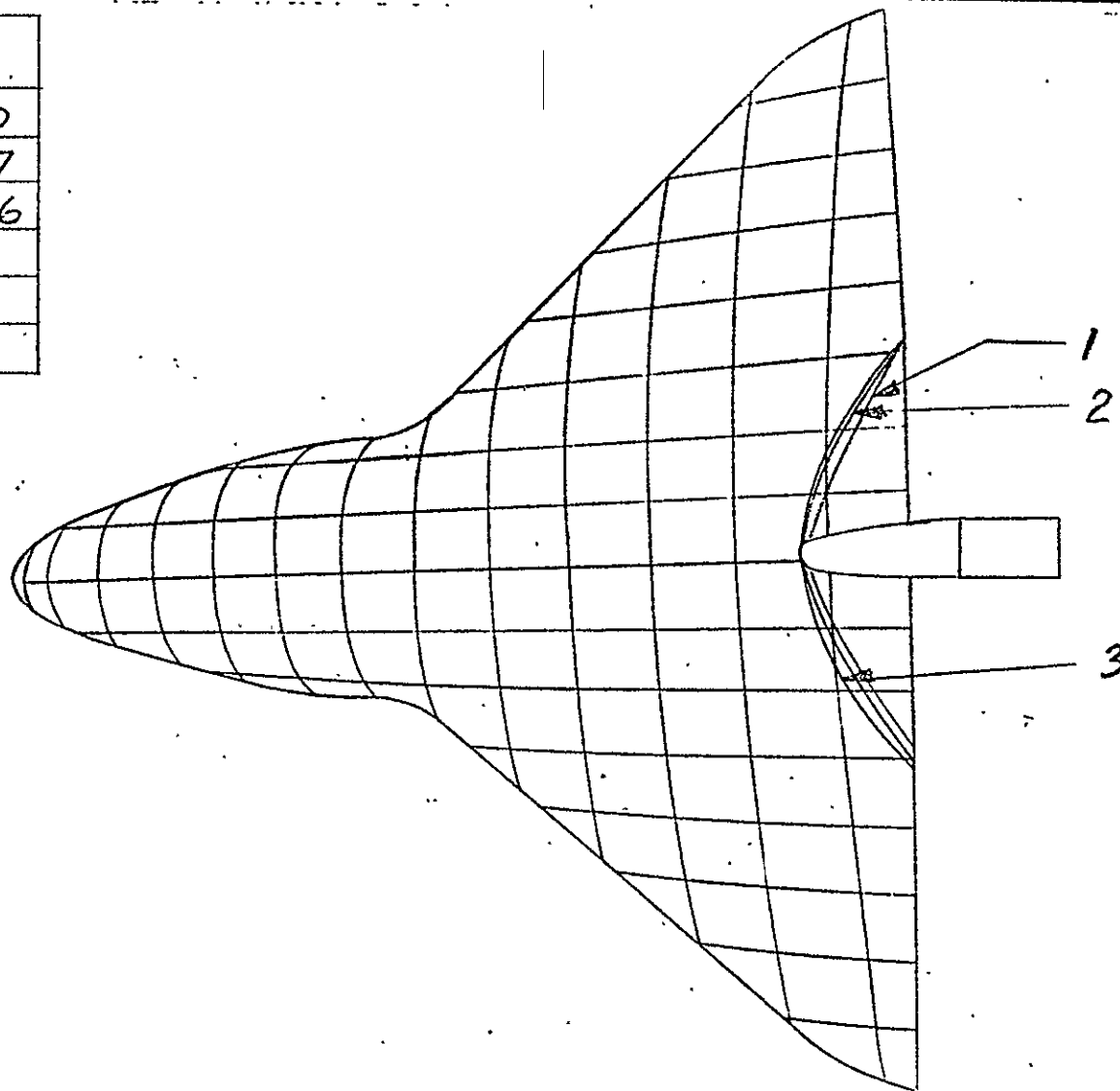
| ISOTHERM NUMBER | h/h_0 |
|-----------------|-----------|
| 1 | 0.151248 |
| 2 | 0.106498 |
| 3 | 0.0868337 |
| 4 | |
| 5 | |
| 6 | |



PHASE CHANGE COATING TEST RUN SHEET

TEST NUMBER: GFHT-017 TEST RUN NUMBER: 071

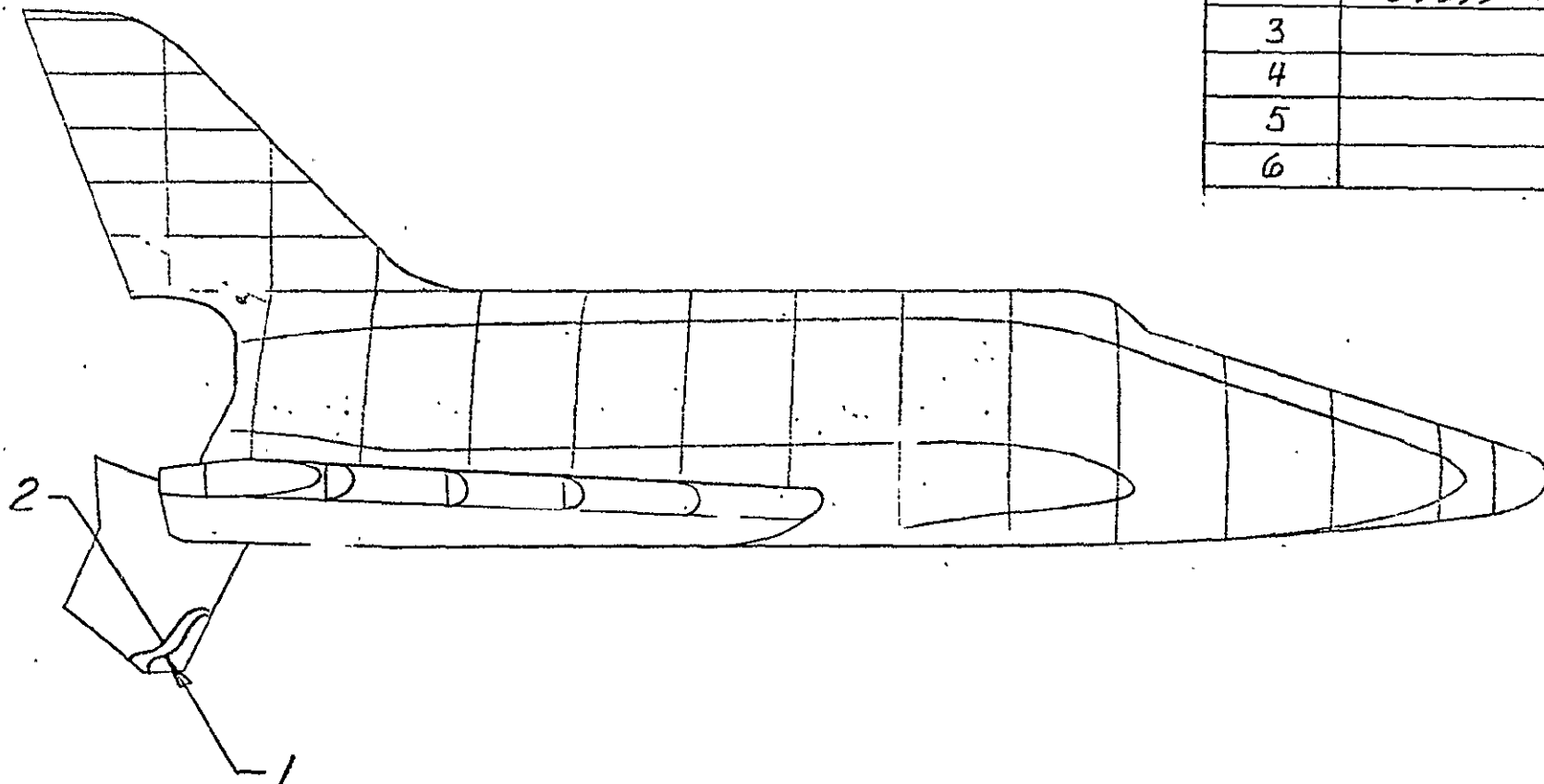
| ISOTHERM NUMBER | $\frac{h}{h_0}$ |
|-----------------|-----------------|
| 1 | 0.169510 |
| 2 | 0.119357 |
| 3 | 0.0973186 |
| 4 | |
| 5 | |
| 6 | |



PHASE CHANGE COATING TEST RUN SHEET

TEST NUMBER: GFHT-017 TEST RUN NUMBER: 068

| ISOTHERM NUMBER | h/h_0 |
|-----------------|-----------|
| 1 | 0.115209 |
| 2 | 0.0939366 |
| 3 | |
| 4 | |
| 5 | |
| 6 | |

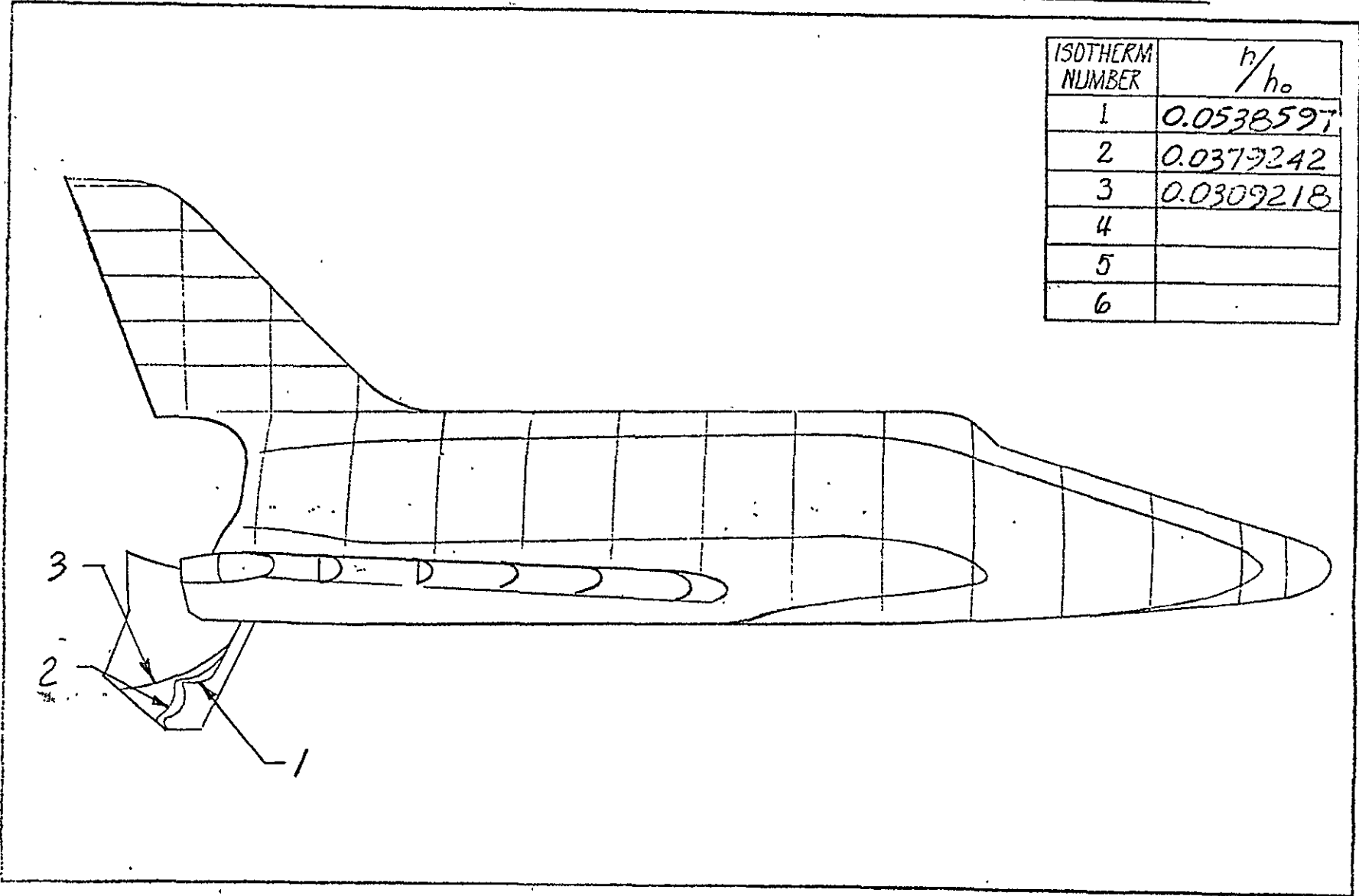


PHASE CHANGE COATING TEST RUN SHEET

TEST NUMBER: GFHT-017

TEST RUN NUMBER: 069

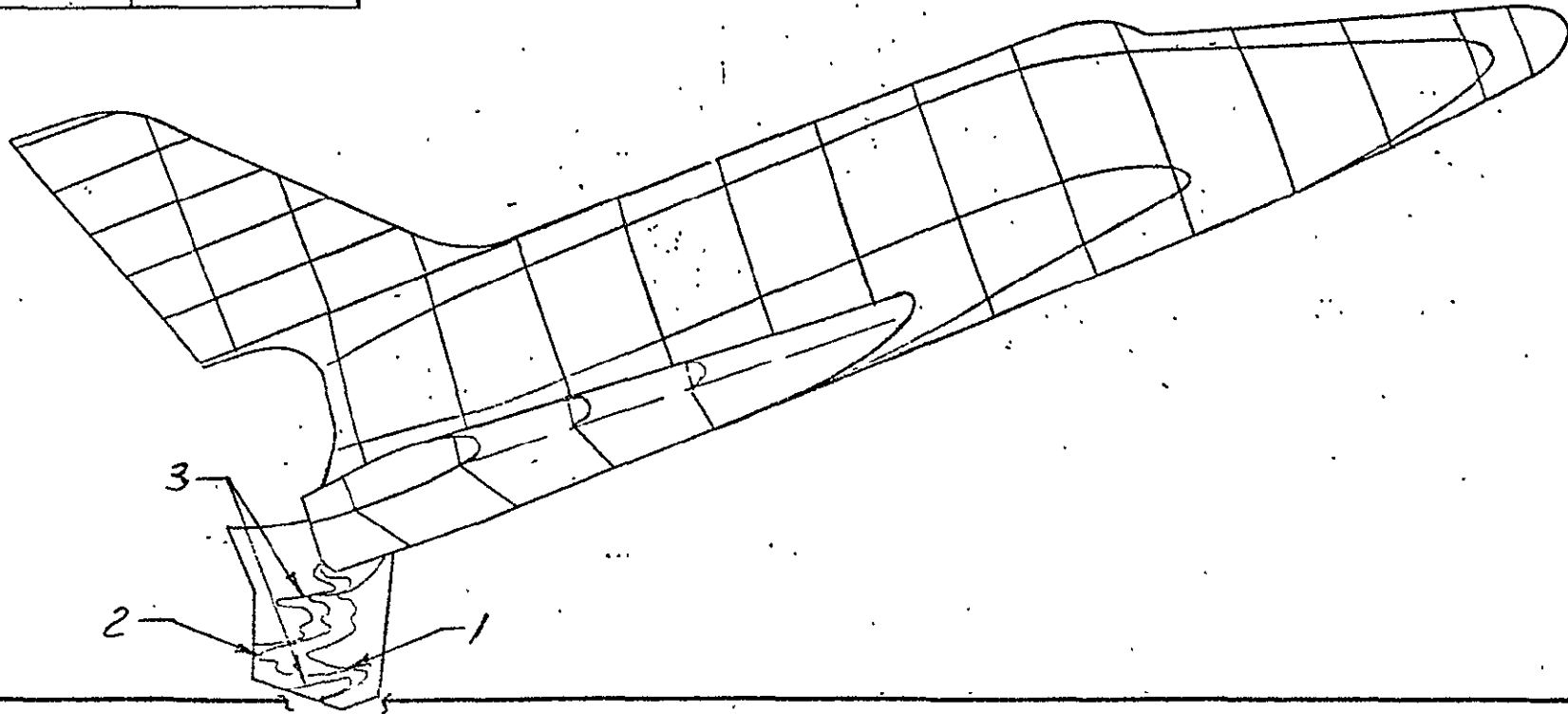
| ISOTHERM NUMBER | h/h_0 |
|-----------------|-----------|
| 1 | 0.0538597 |
| 2 | 0.0379242 |
| 3 | 0.0309218 |
| 4 | |
| 5 | |
| 6 | |



PHASE CHANGE COATING TEST RUN SHEET

TEST NUMBER: GFHT-017 TEST RUN NUMBER: 067

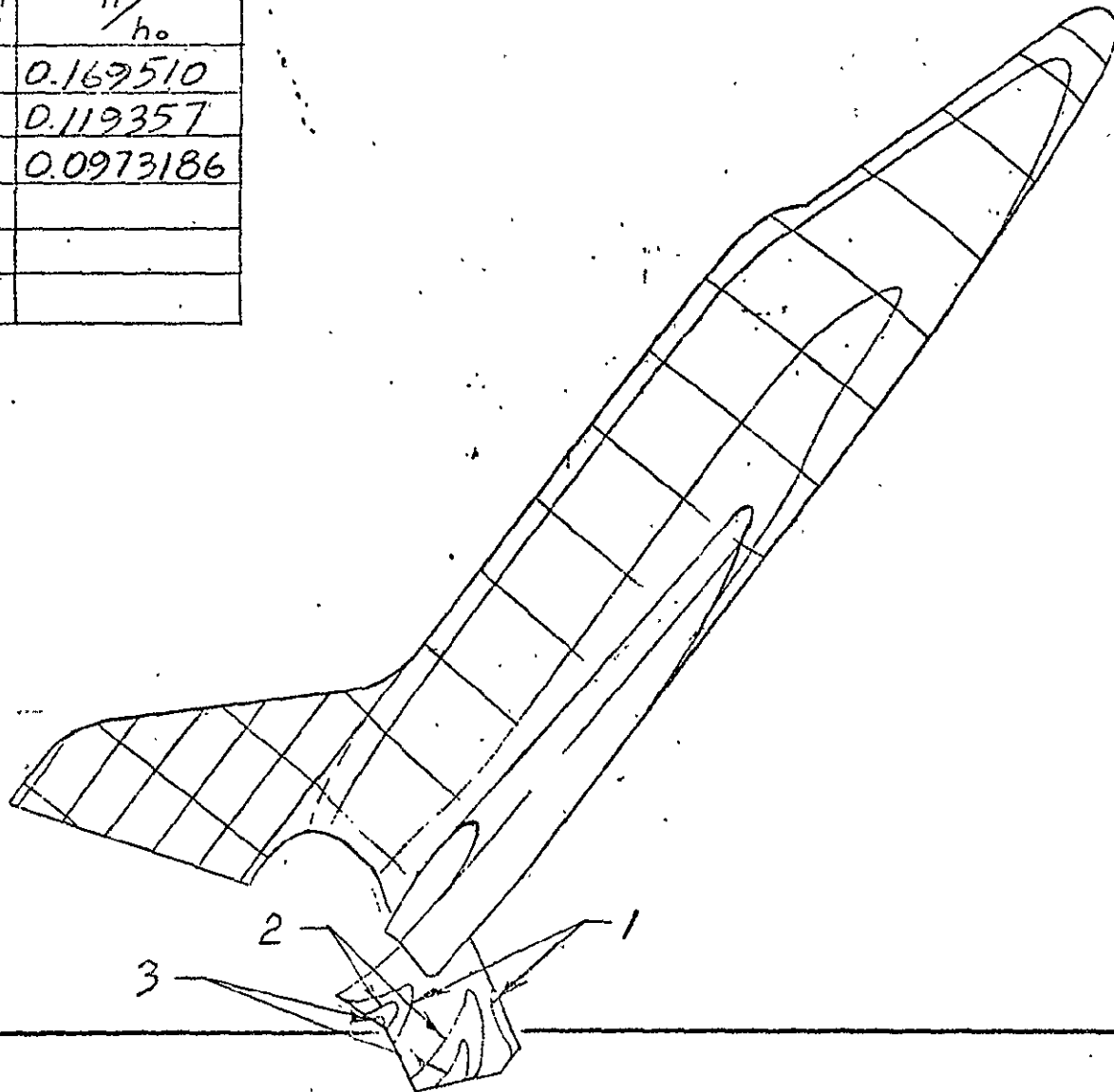
| ISOTHERM NUMBER | h/h_0 |
|-----------------|-----------|
| 1 | 0.151248 |
| 2 | 0.106498 |
| 3 | 0.0868337 |
| 4 | |
| 5 | |
| 6 | |



PHASE CHANGE COATING TEST RUN SHEET

TEST NUMBER: GFHT-017 TEST RUN NUMBER: 071

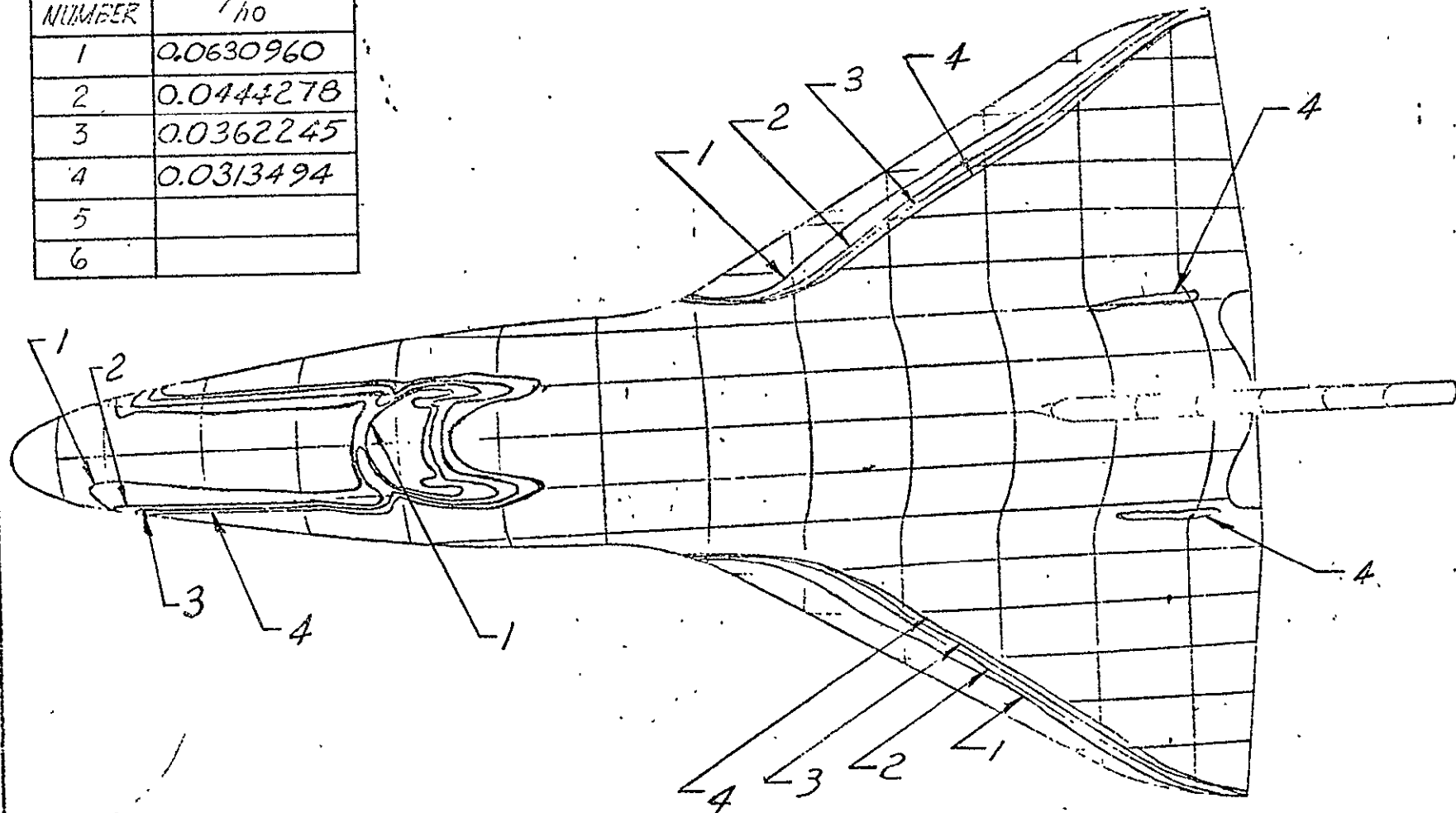
| ISOTHERM NUMBER | h/h_0 |
|-----------------|-----------|
| 1 | 0.169510 |
| 2 | 0.119357 |
| 3 | 0.0973186 |
| 4 | |
| 5 | |
| 6 | |



PHASE CHANGE COATING TEST RUN SHEET

TEST NUMBER: GFHT-017 TEST RUN NUMBER: 011

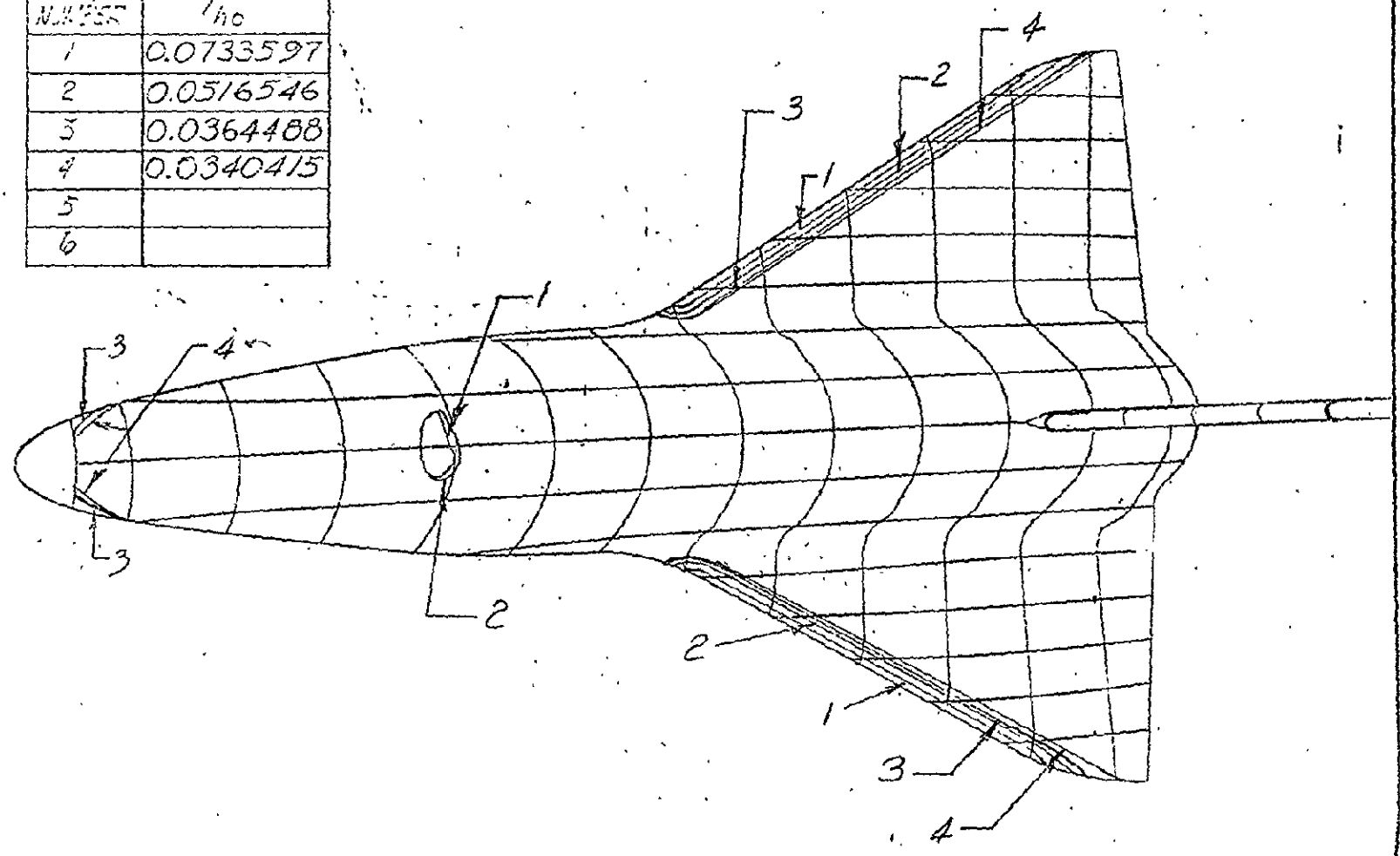
| ISOTHERM NUMBER | t_i / t_0 |
|-----------------|-------------|
| 1 | 0.0630960 |
| 2 | 0.0444278 |
| 3 | 0.0362245 |
| 4 | 0.0313494 |
| 5 | |
| 6 | |



PHASE CHANGE COATING TEST RUN SHEET

TEST NUMBER: GFHT-017 TEST RUN NUMBER: 014

| TEST NUMBER | h/h_0 |
|-------------|-----------|
| 1 | 0.0733597 |
| 2 | 0.0516546 |
| 3 | 0.0364488 |
| 4 | 0.0340415 |
| 5 | |
| 6 | |

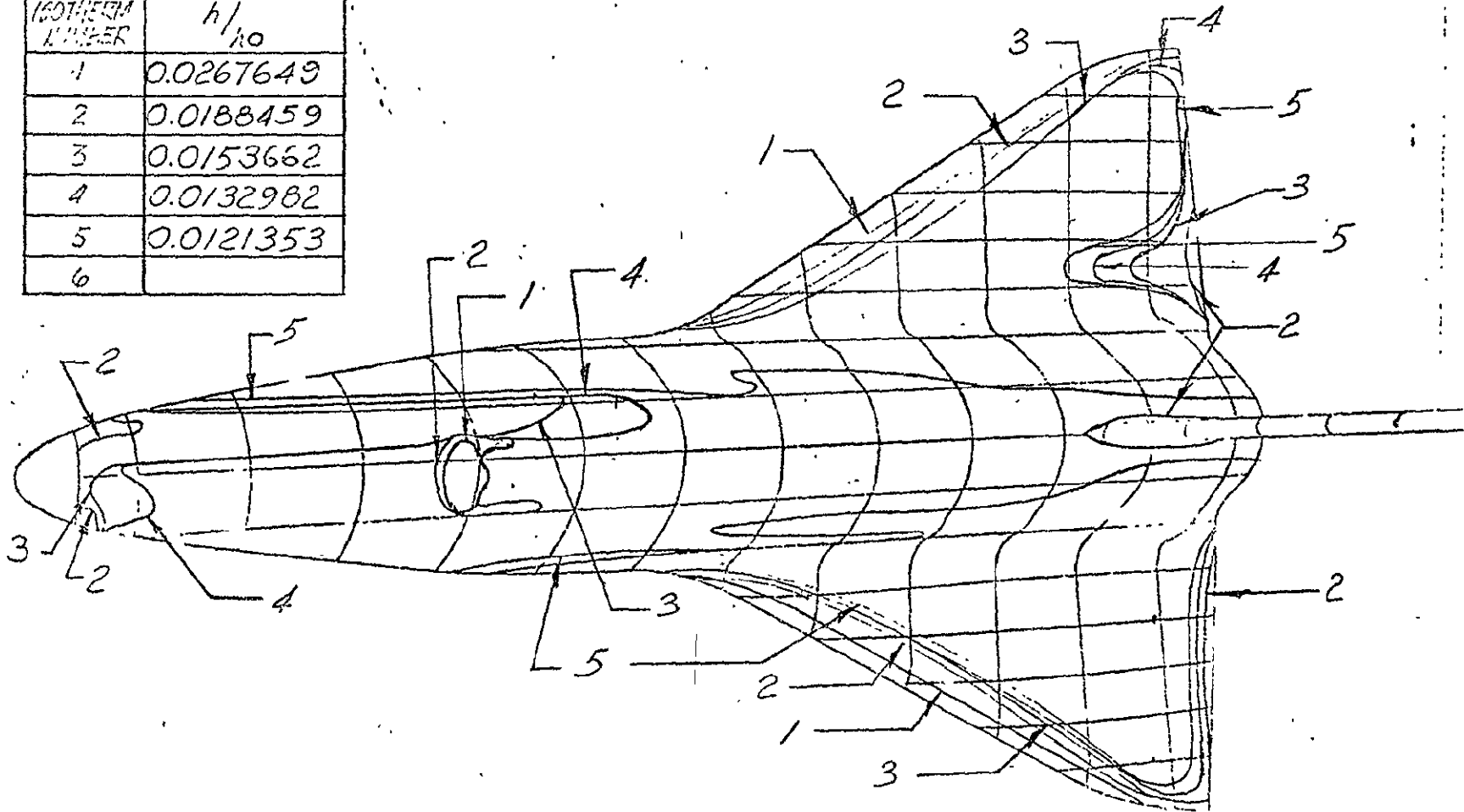


PHASE CHANGE COATING TEST RUN SHEET

TEST NUMBER: GFHT-017

TEST RUN NUMBER: 032

| ISOTHERM NUMBER | h/k_0 |
|-----------------|-----------|
| 1 | 0.0267649 |
| 2 | 0.0188459 |
| 3 | 0.0153662 |
| 4 | 0.0132982 |
| 5 | 0.0121353 |
| 6 | |

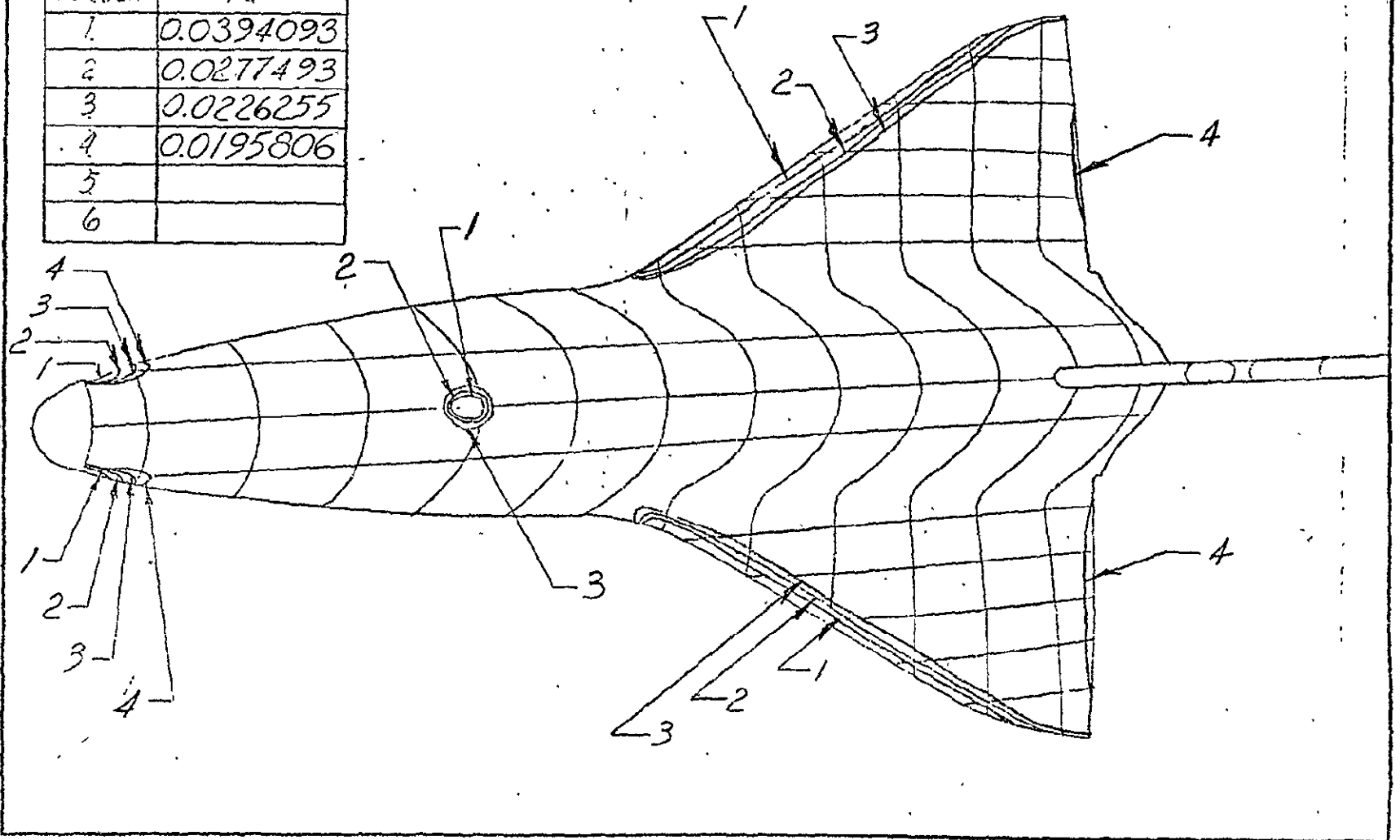


11

PHASE CHANGE COATING TEST RUN SHEET

TEST NUMBER: GFHT-017 TEST RUN NUMBER: 018

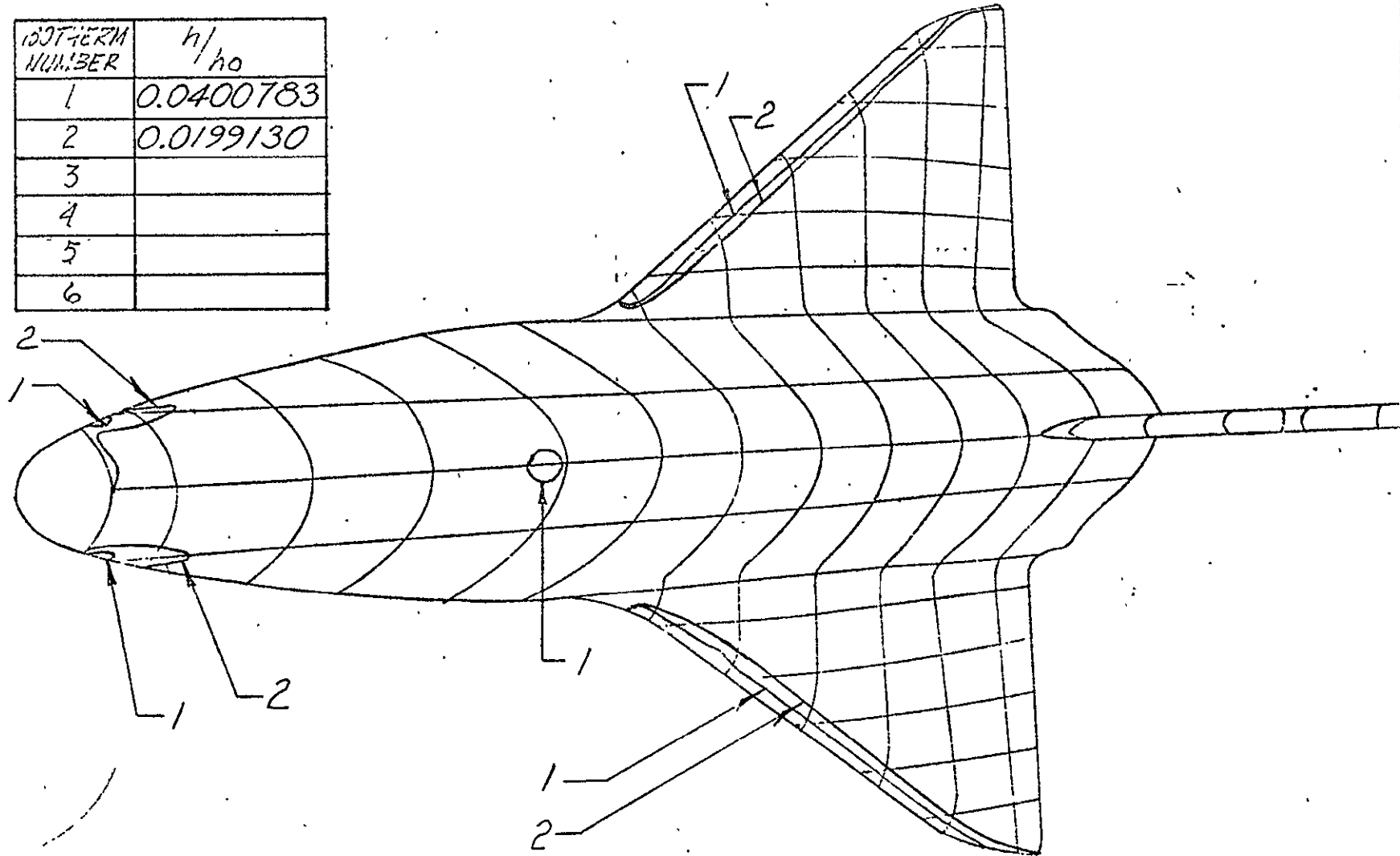
| SUBSTRATE NUMBER | μ/m |
|------------------|-----------|
| 1 | 0.0394093 |
| 2 | 0.0277493 |
| 3 | 0.0226255 |
| 4 | 0.0195806 |
| 5 | |
| 6 | |



PHASE CHANGE COATING TEST RUN SHEET

TEST NUMBER: GFHT-017 TEST RUN NUMBER: 021

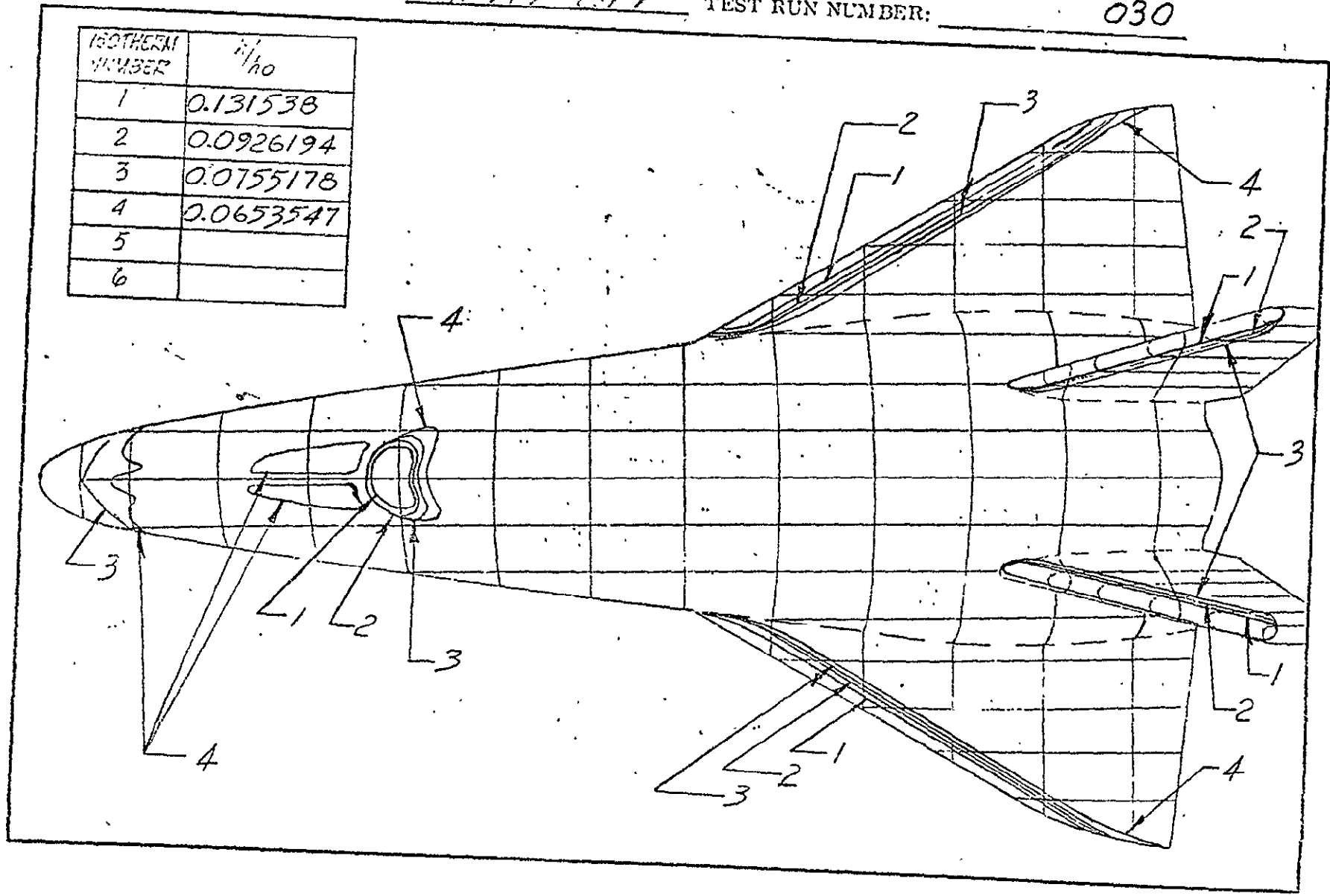
| DOT TERM NUMBER | h/h_0 |
|-----------------|-----------|
| 1 | 0.0400783 |
| 2 | 0.0199130 |
| 3 | |
| 4 | |
| 5 | |
| 6 | |



PHASE CHANGE COATING TEST RUN SHEET

TEST NUMBER: GFHT-017 TEST RUN NUMBER: 030

| ISOTHERM NUMBER | t_i/h_0 |
|-----------------|-----------|
| 1 | 0.131538 |
| 2 | 0.0926194 |
| 3 | 0.0755178 |
| 4 | 0.0653547 |
| 5 | |
| 6 | |

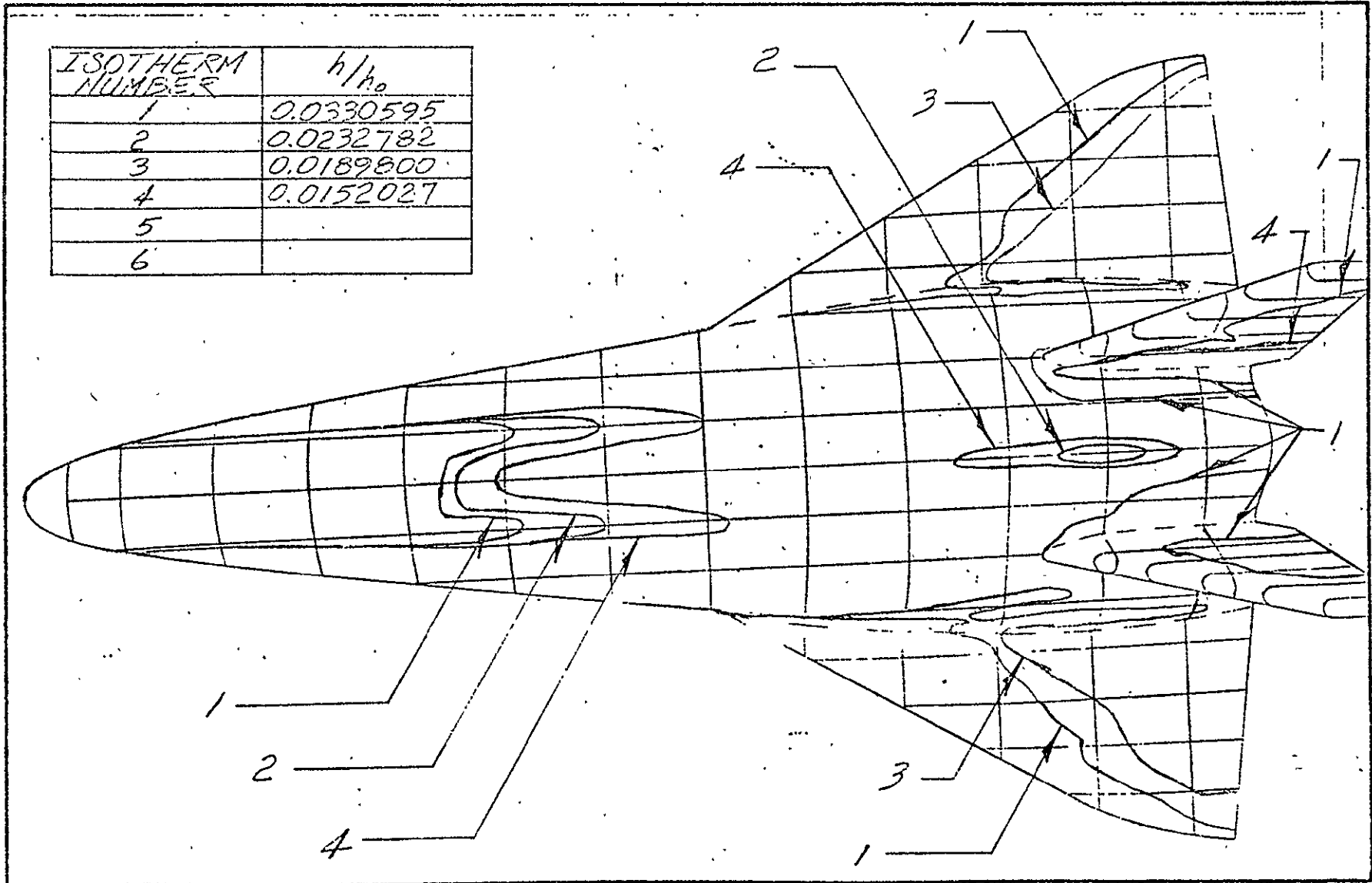


PHASE CHANGE COATING TEST RUN SHEET

TEST NUMBER: GFHT-017

TEST RUN NUMBER: 031

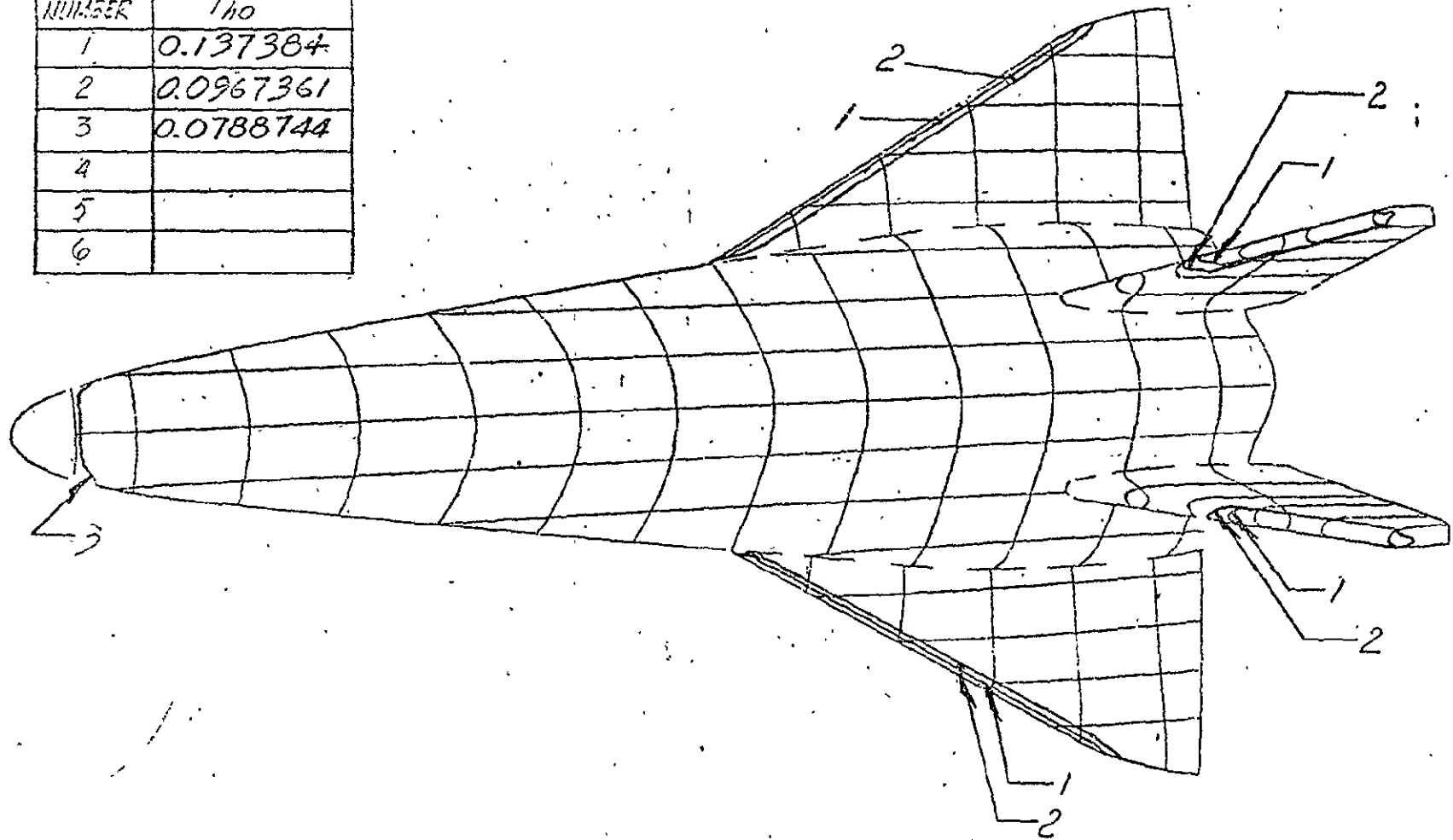
| ISOTHERM NUMBER | h/h_0 |
|-----------------|-----------|
| 1 | 0.0330595 |
| 2 | 0.0232782 |
| 3 | 0.0189800 |
| 4 | 0.0152027 |
| 5 | |
| 6 | |



PHASE CHANGE COATING TEST RUN SHEET

TEST NUMBER: GFHT-017 TEST RUN NUMBER: 029

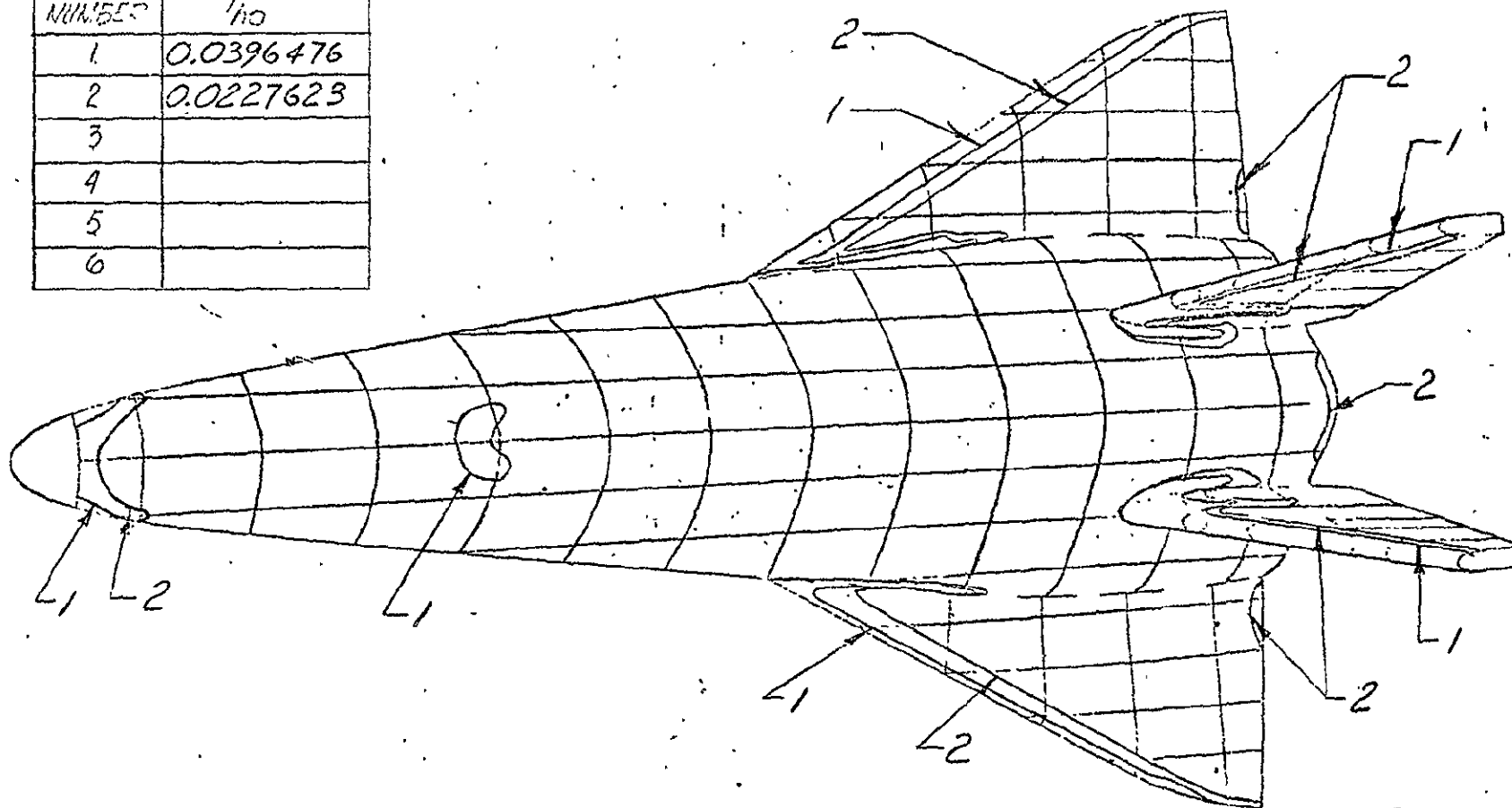
| ISOTHERM NUMBER | t/t_0 |
|-----------------|-----------|
| 1 | 0.137384 |
| 2 | 0.0967361 |
| 3 | 0.0788744 |
| 4 | |
| 5 | |
| 6 | |



PHASE CHANGE COATING TEST RUN SHEET

TEST NUMBER: GFHT-017 TEST RUN NUMBER: 028

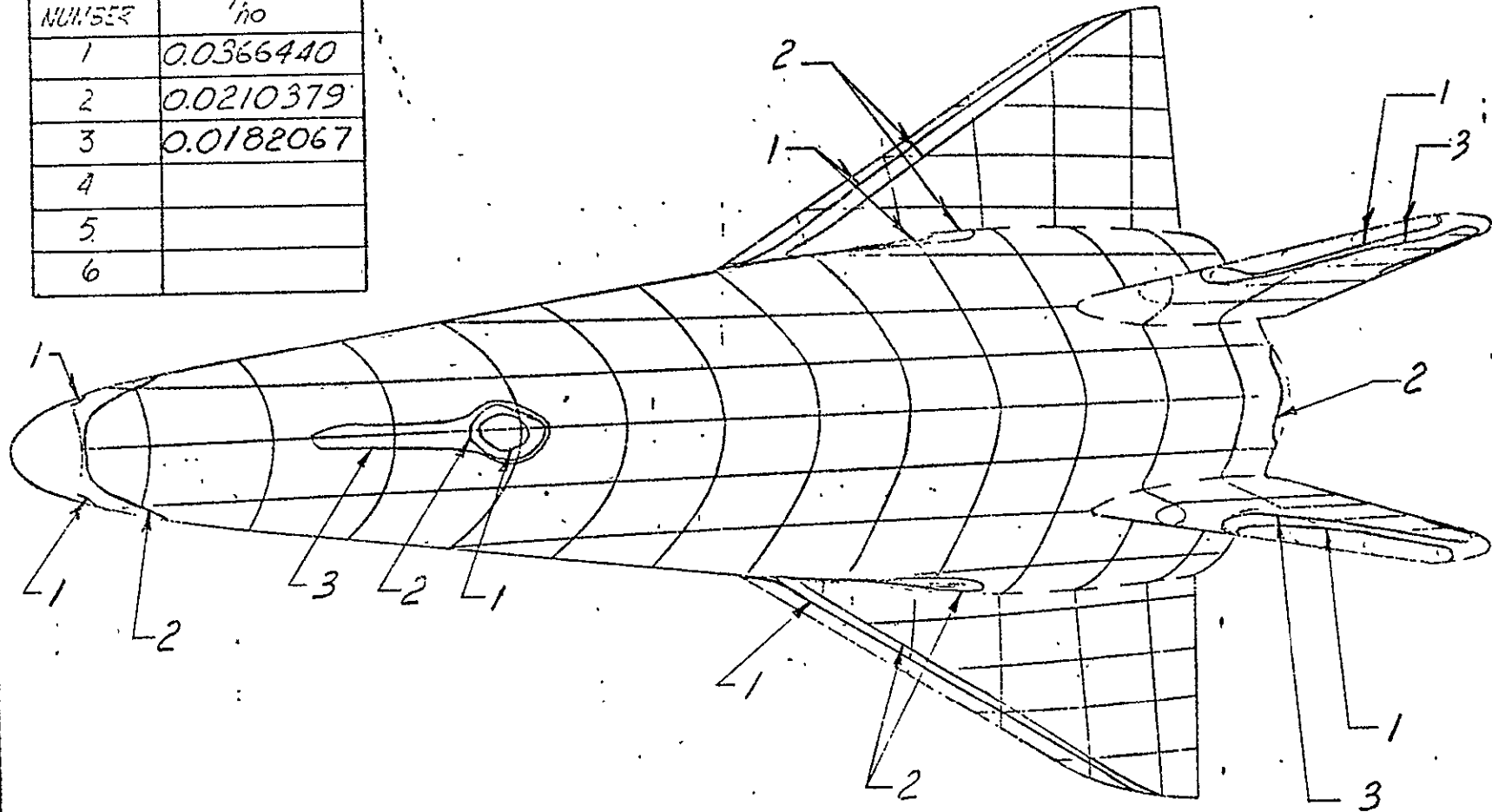
| ISOTHERM NUMBER | h/h ₀ |
|-----------------|------------------|
| 1 | 0.0396476 |
| 2 | 0.0227623 |
| 3 | |
| 4 | |
| 5 | |
| 6 | |



PHASE CHANGE COATING TEST RUN SHEET

TEST NUMBER: CFHT-017 TEST RUN NUMBER: 026

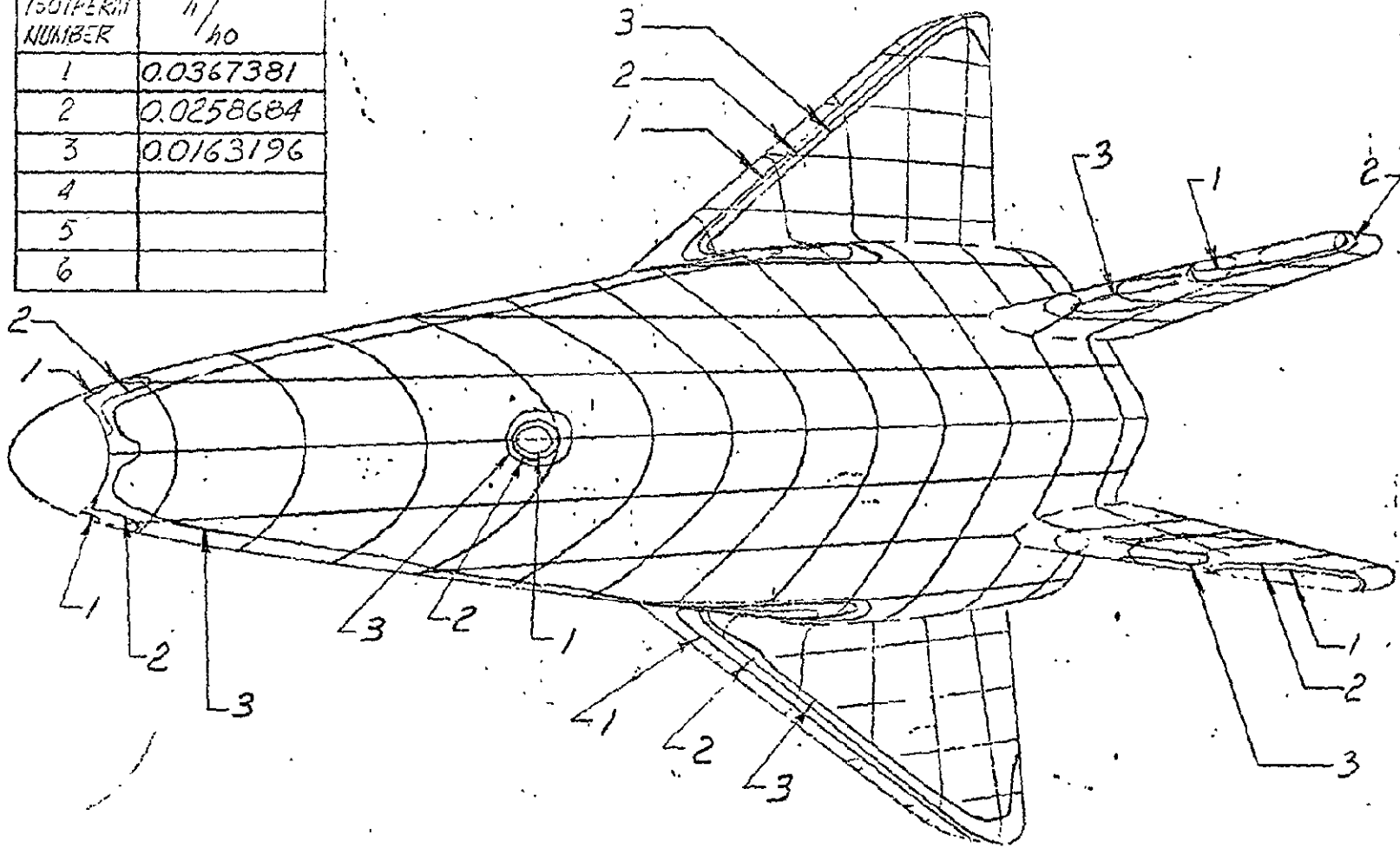
| TEOTERM NUMBER | n _i / n _o |
|-------------------|------------------------------------|
| 1 | 0.0366440 |
| 2 | 0.0210379 |
| 3 | 0.0182067 |
| 4 | |
| 5 | |
| 6 | |



PHASE CHANGE COATING TEST RUN SHEET

TEST NUMBER: GFHT-017 TEST RUN NUMBER: 024

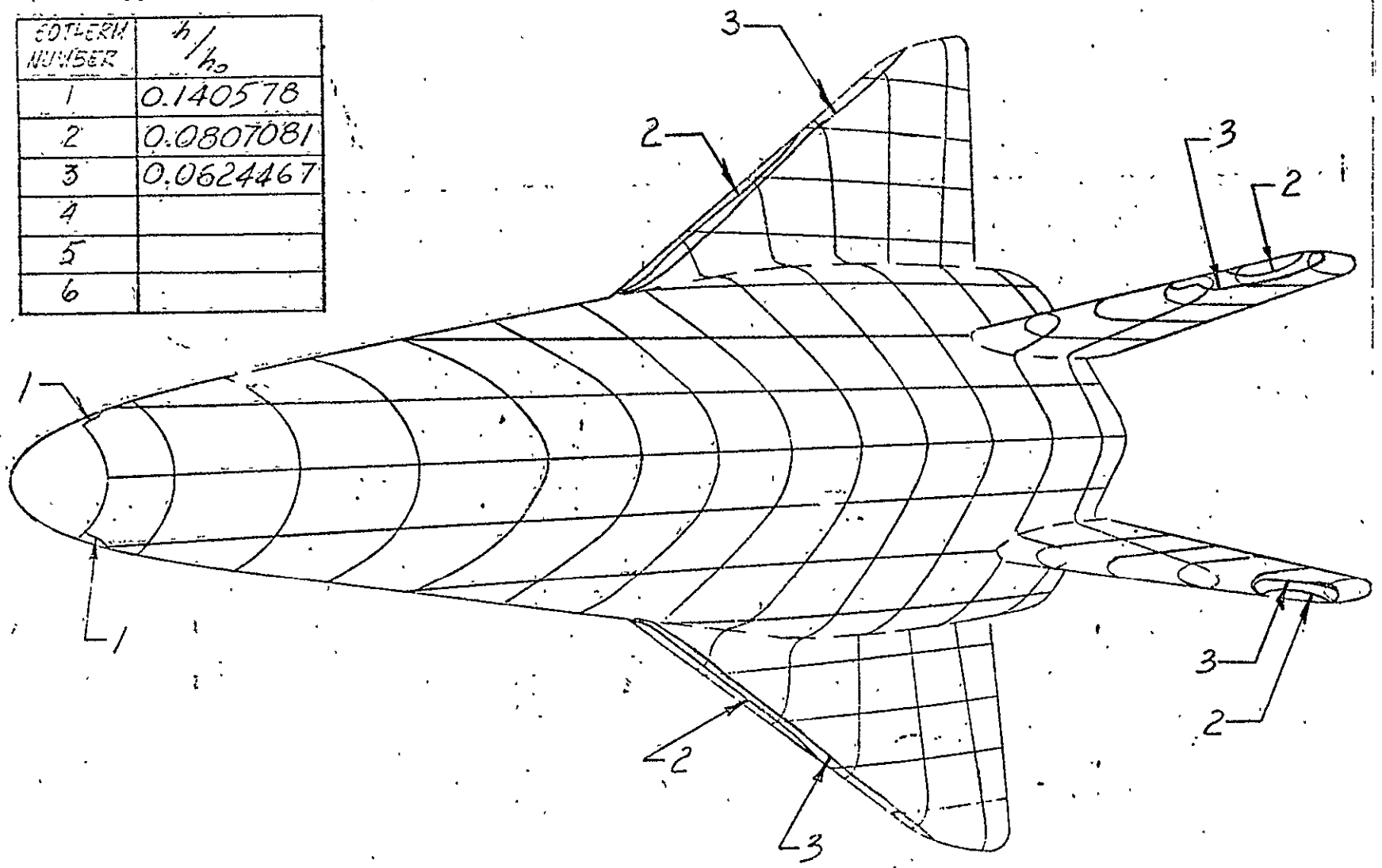
| ISOTHERM NUMBER | $\frac{11}{10}$ |
|-----------------|-----------------|
| 1 | 0.0367381 |
| 2 | 0.0258684 |
| 3 | 0.0163196 |
| 4 | |
| 5 | |
| 6 | |



PHASE CHANGE COATING TEST RUN SHEET

TEST NUMBER: GFHT-017 TEST RUN NUMBER: 023

| SPHERICAL NUMBER | h/h_0 |
|------------------|-----------|
| 1 | 0.140578 |
| 2 | 0.0807081 |
| 3 | 0.0624467 |
| 4 | |
| 5 | |
| 6 | |

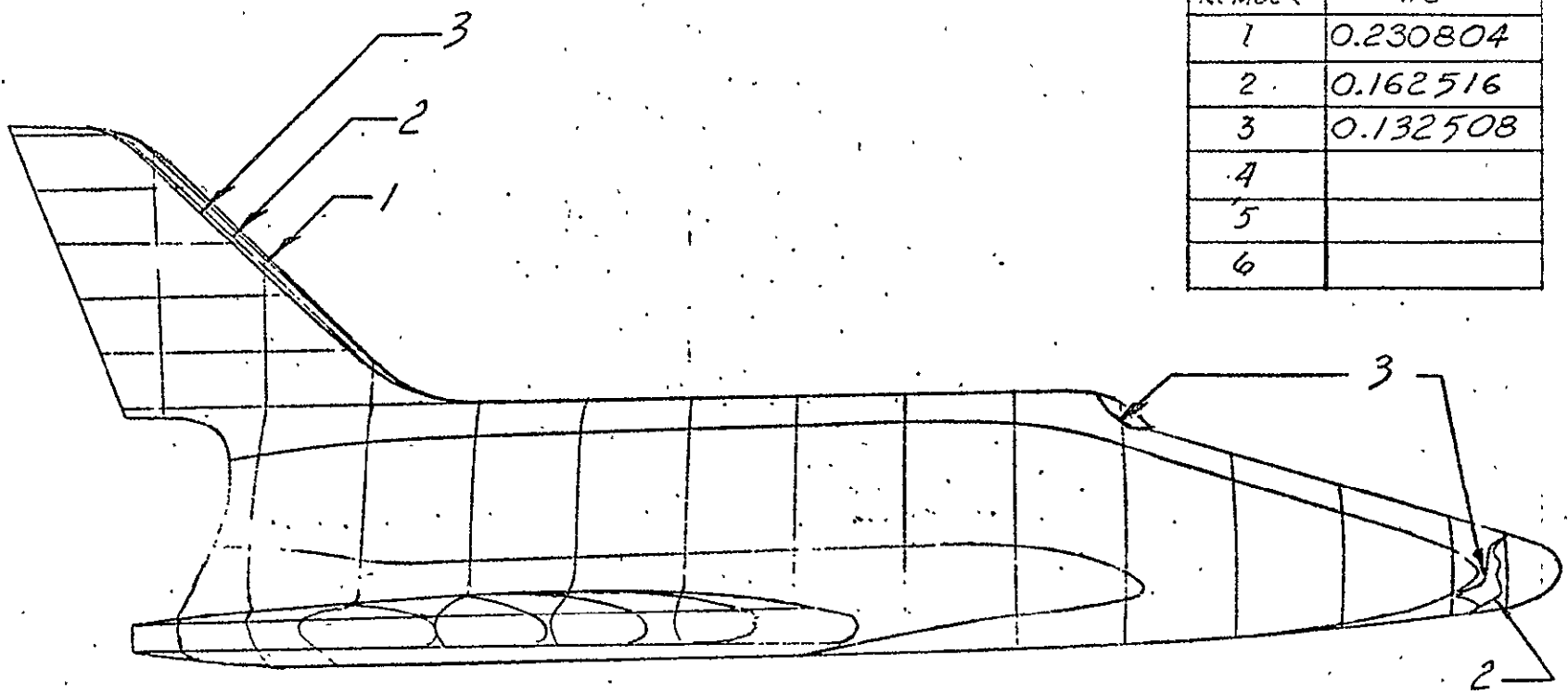


PHASE CHANGE COATING TEST RUN SHEET

TEST NUMBER: GFHT-017

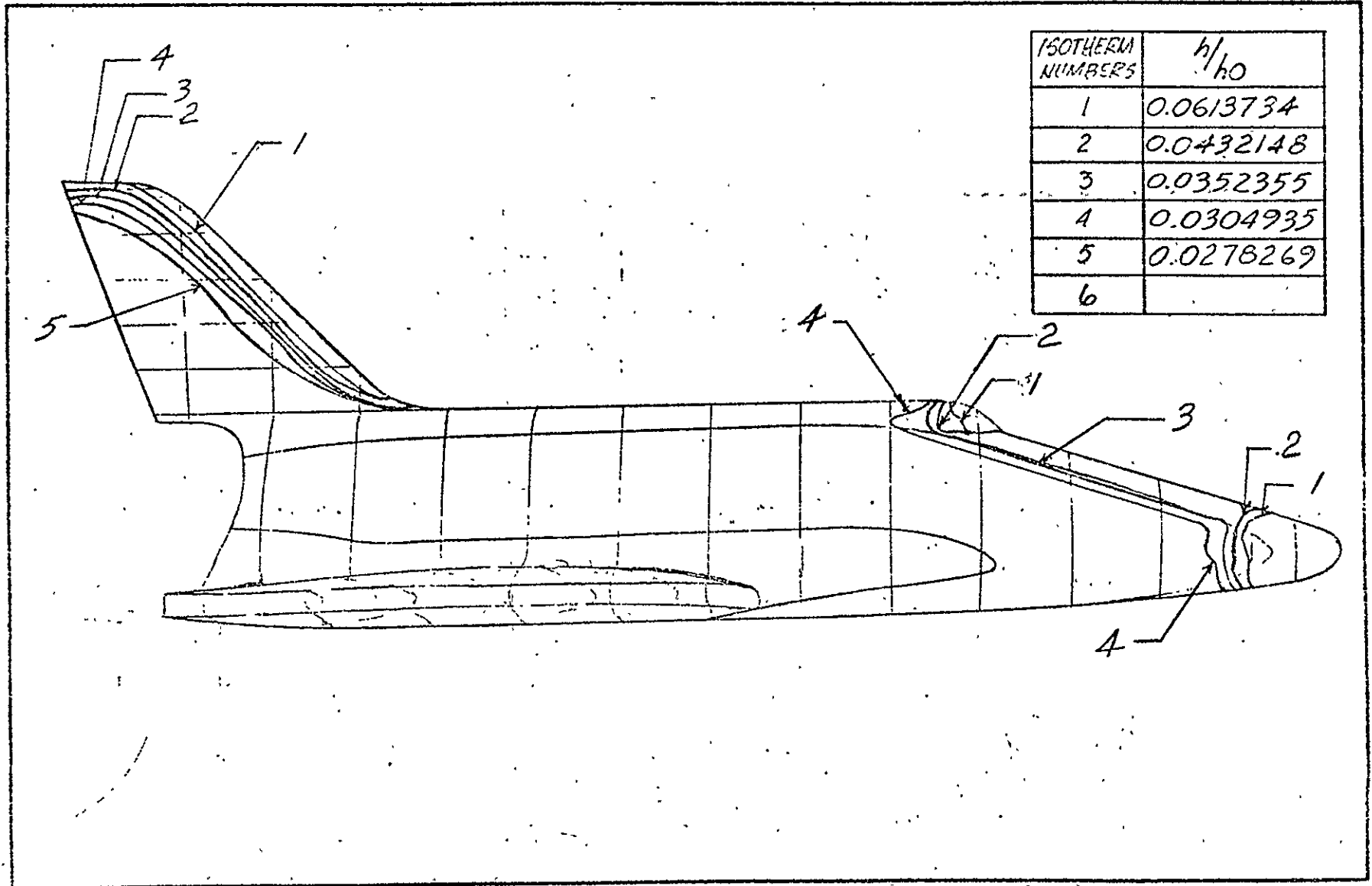
TEST RUN NUMBER: 002

| ISOTHERM NUMBER | h/h_0 |
|-----------------|----------|
| 1 | 0.230804 |
| 2 | 0.162516 |
| 3 | 0.132508 |
| 4 | |
| 5 | |
| 6 | |



PHASE CHANGE COATING TEST RUN SHEET

TEST NUMBER: GFHT-017 TEST RUN NUMBER: 009

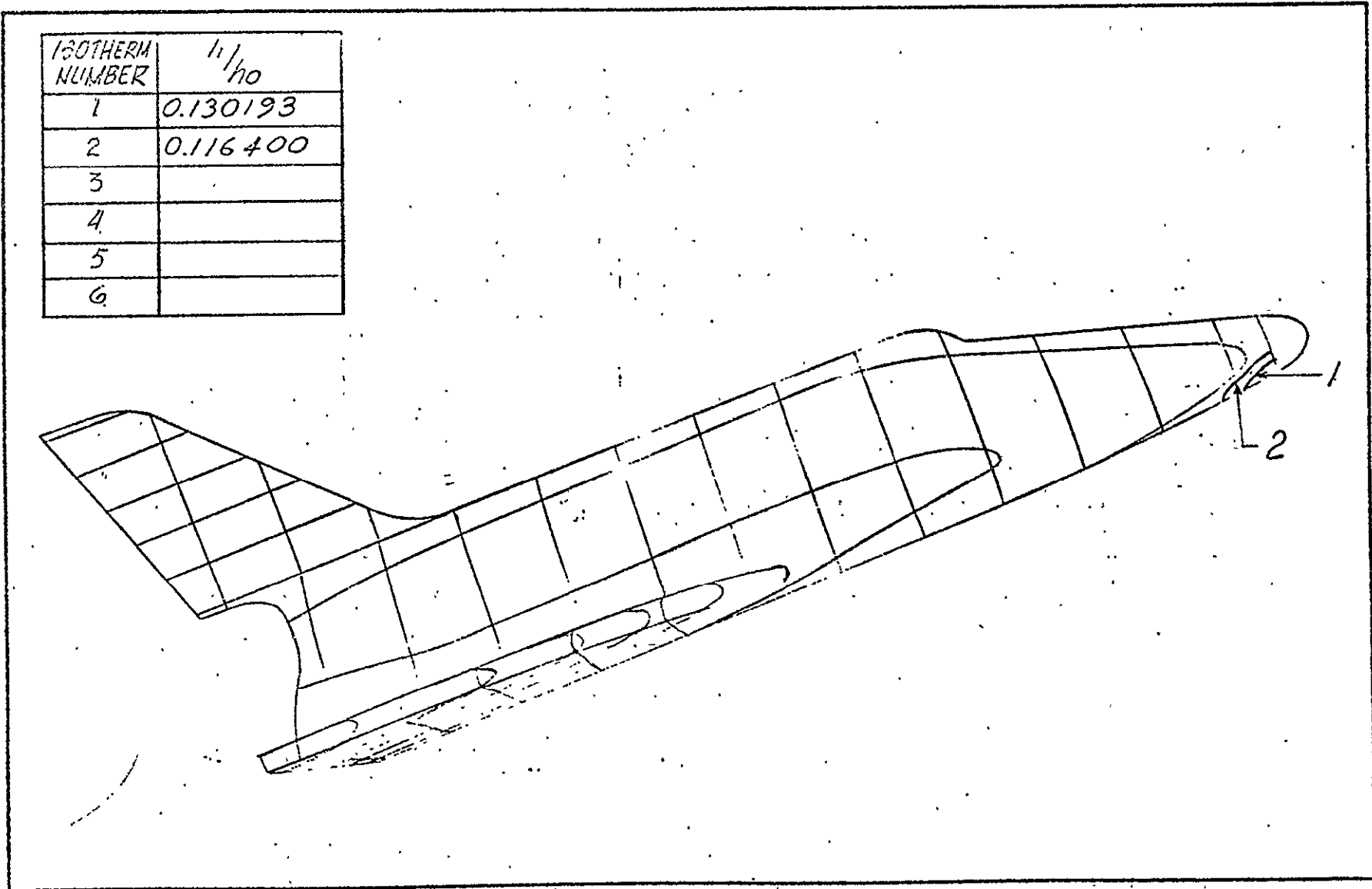


2
⊕

PHASE CHANGE COATING TEST RUN SHEET

TEST NUMBER: GFHT-017 TEST RUN NUMBER: 005

| ISOTHERM NUMBER | t_i/t_o |
|-----------------|-----------|
| 1 | 0.130193 |
| 2 | 0.116400 |
| 3 | |
| 4 | |
| 5 | |
| 6 | |

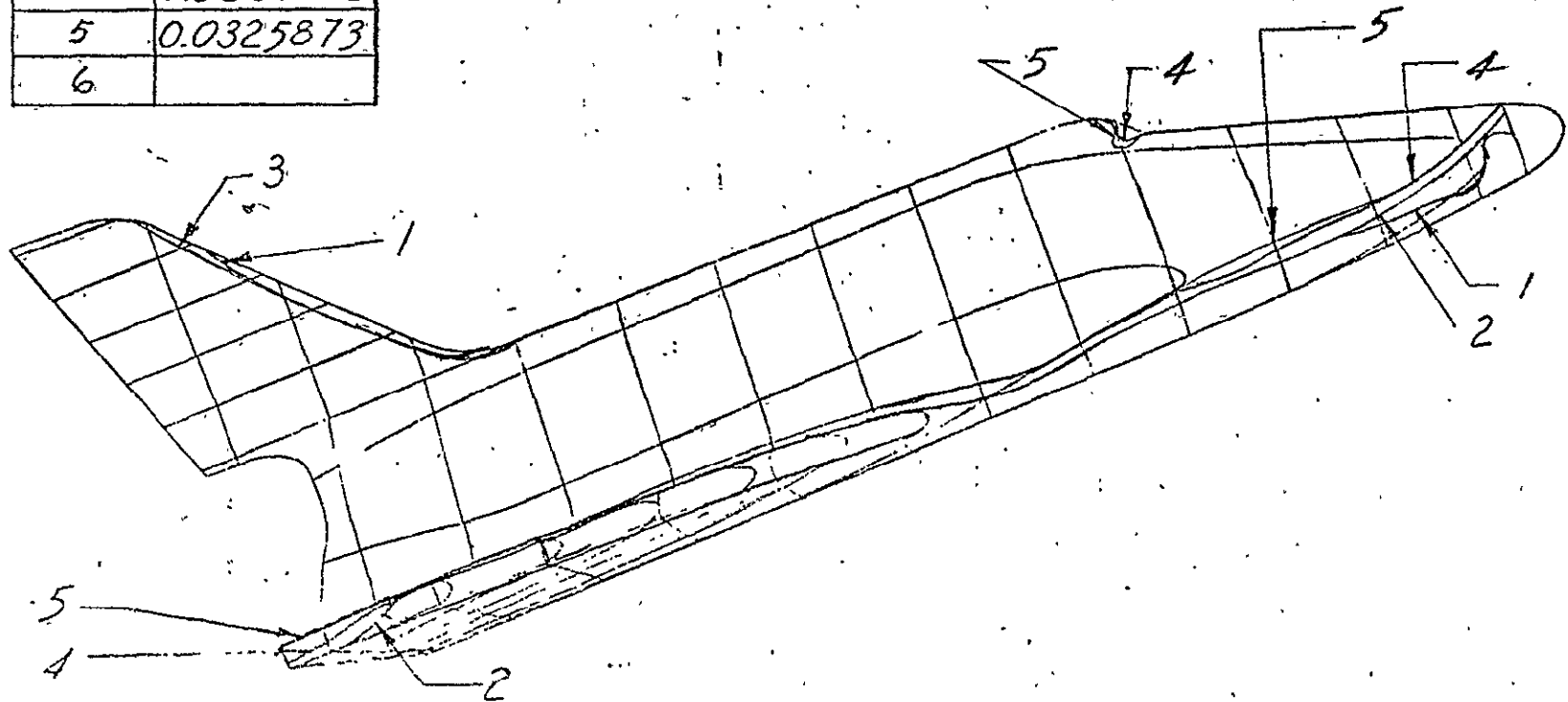


31

PHASE CHANGE COATING TEST RUN SHEET

TEST NUMBER: GEHT-017 TEST RUN NUMBER: 014

| SECTION NUMBERS | n/ho |
|--------------------|-----------|
| 1 | 0.0733597 |
| 2 | 0.0516546 |
| 3 | 0.0421169 |
| 4 | 0.0364480 |
| 5 | 0.0325873 |
| 6 | |

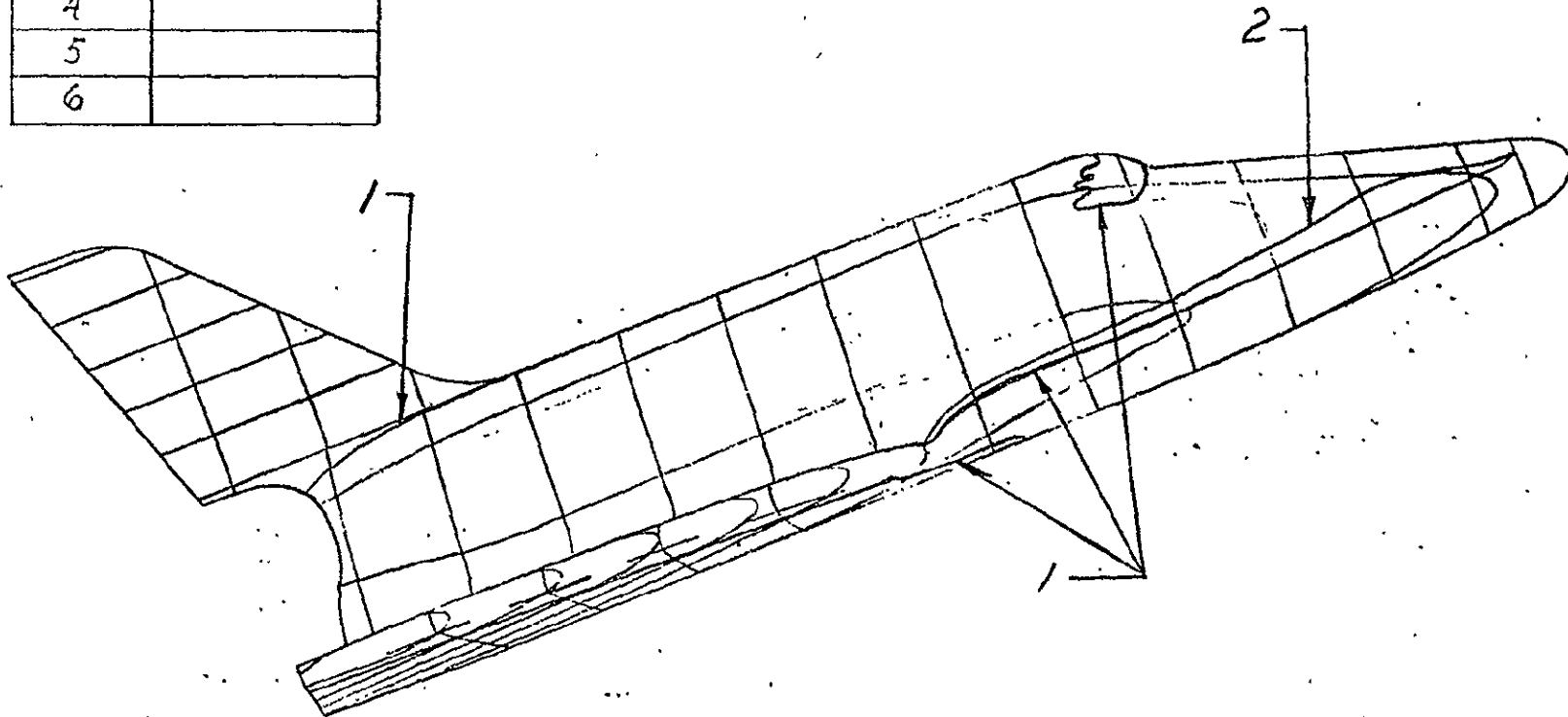


PHASE CHANGE COATING TEST RUN SHEET

TEST NUMBER: GFHT - 017

TEST RUN NUMBER: -032

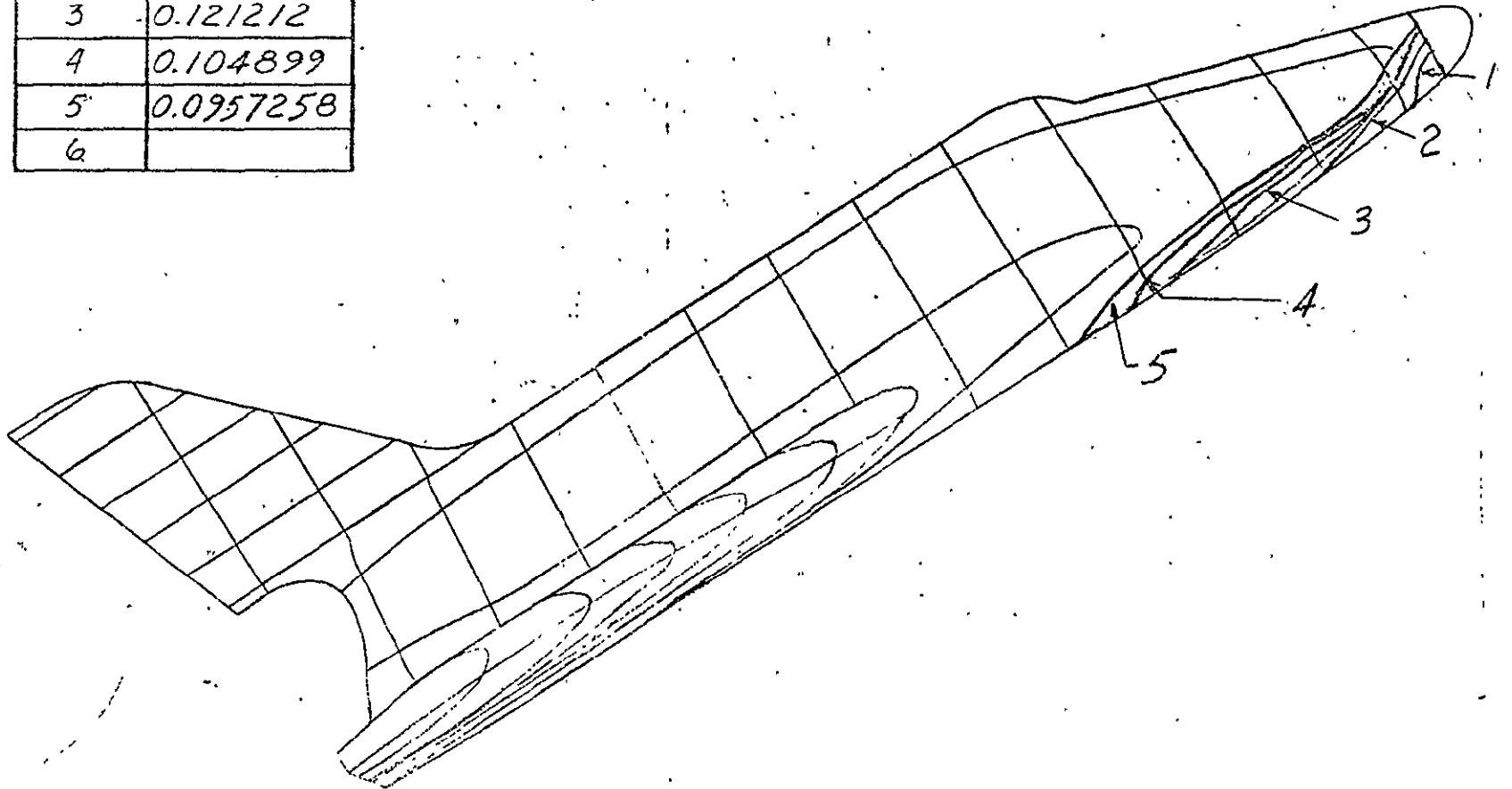
| ISOOTHERM NUMBERS | h/h_0 |
|----------------------|-----------|
| 1 | 0.0267649 |
| 2 | 0.0132982 |
| 3 | |
| 4 | |
| 5 | |
| 6 | |



PHASE CHANGE COATING TEST RUN SHEET

TEST TEST TEST TEST NUMBER: GFHT-017 TEST RUN NUMBER: 007

| POSITION NUMBER | Wt. % |
|-----------------|-----------|
| 1 | 0.211127 |
| 2 | 0.148661 |
| 3 | 0.121212 |
| 4 | 0.104899 |
| 5 | 0.0957258 |
| 6 | |

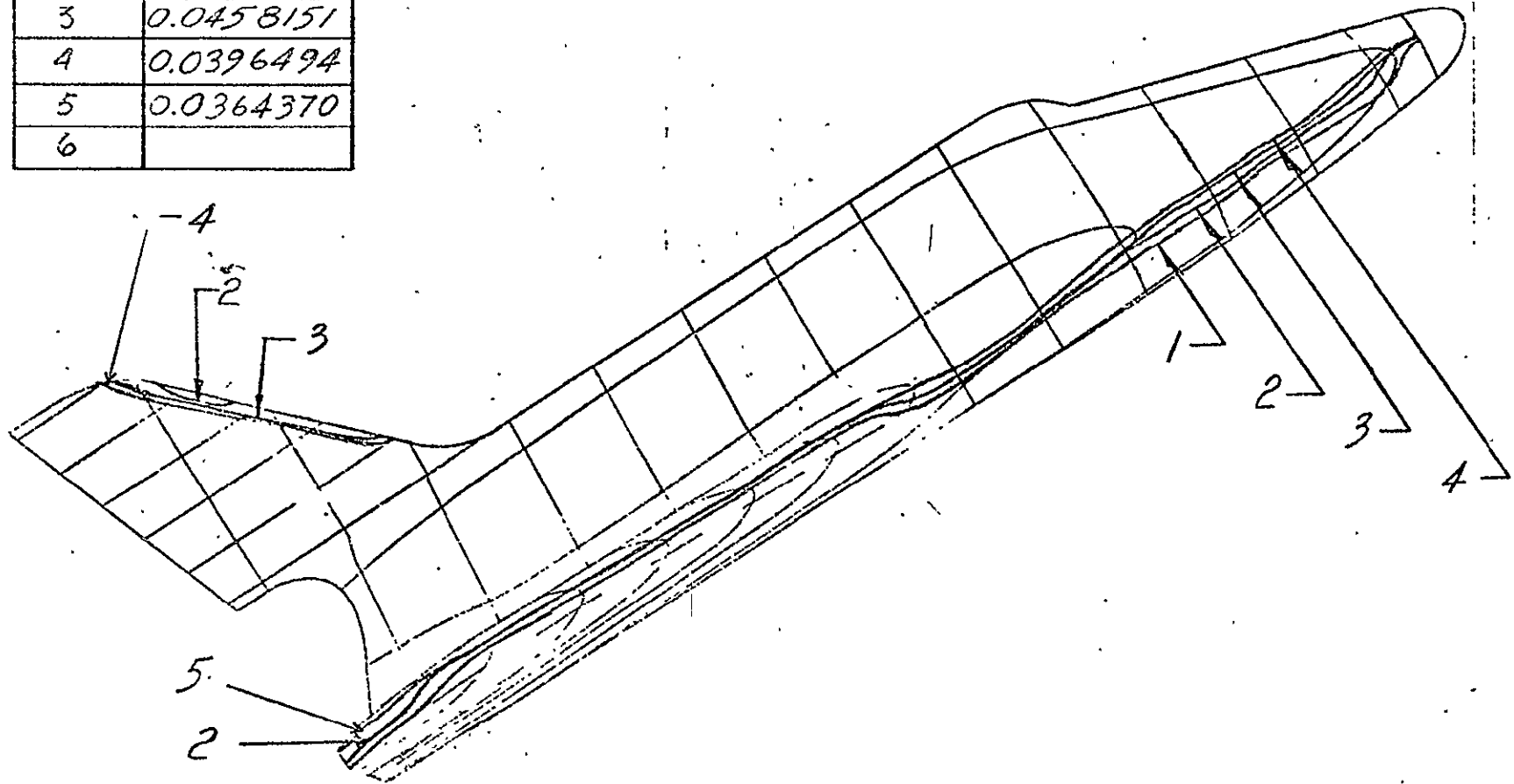


PHASE CHANGE COATING TEST RUN SHEET

TEST NUMBER: GFHT-017

TEST RUN NUMBER: 008

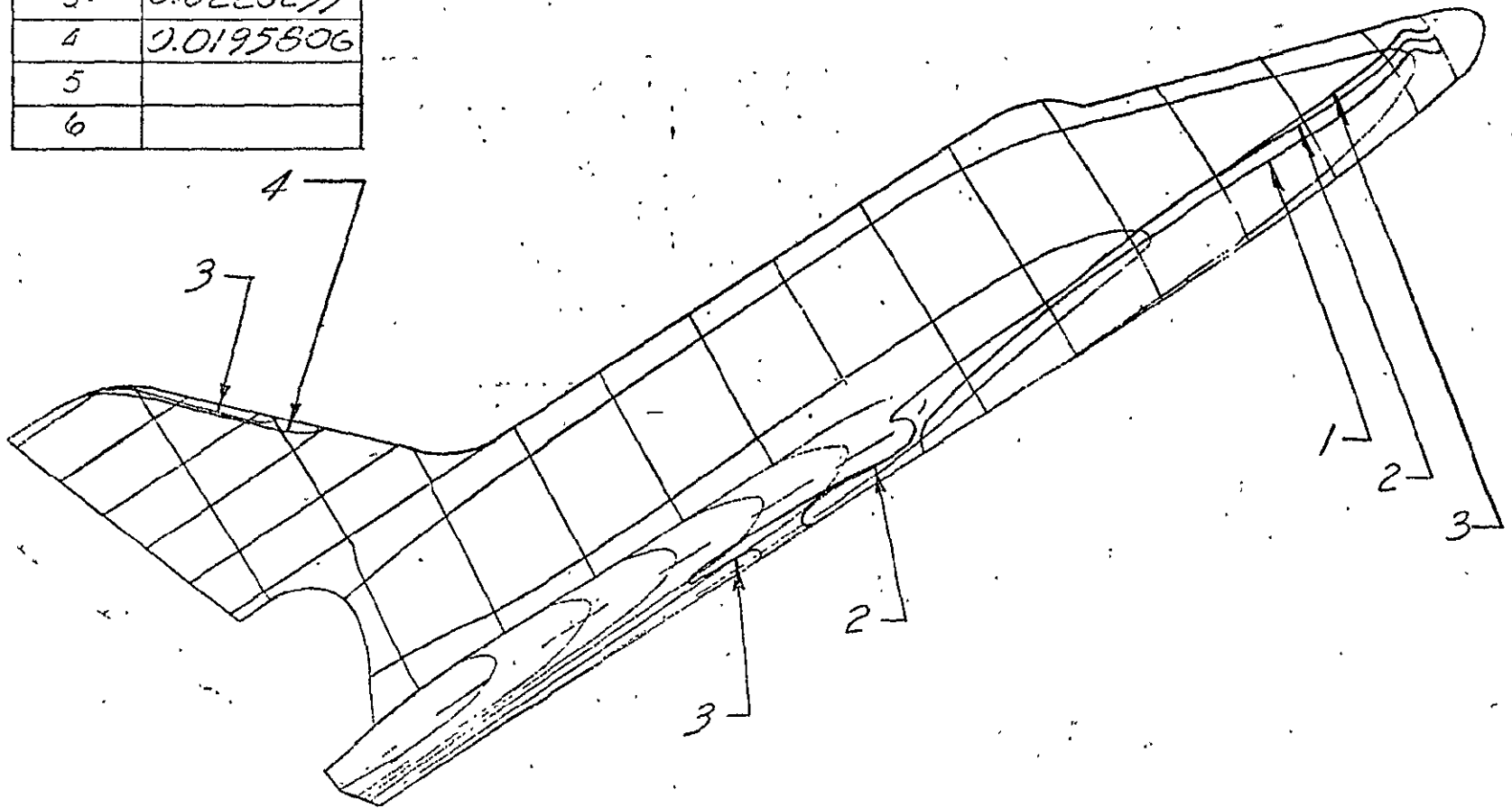
| ISOTHERM NUMBERS | h/h_0 |
|------------------|-----------|
| 1 | 0.0798012 |
| 2 | 0.0561903 |
| 3 | 0.0458151 |
| 4 | 0.0396494 |
| 5 | 0.0364370 |
| 6 | |



PHASE CHANGE COATING TEST RUN SHEET

TEST TYPE: TEST NUMBER: GFHT-017 TEST RUN NUMBER: 018

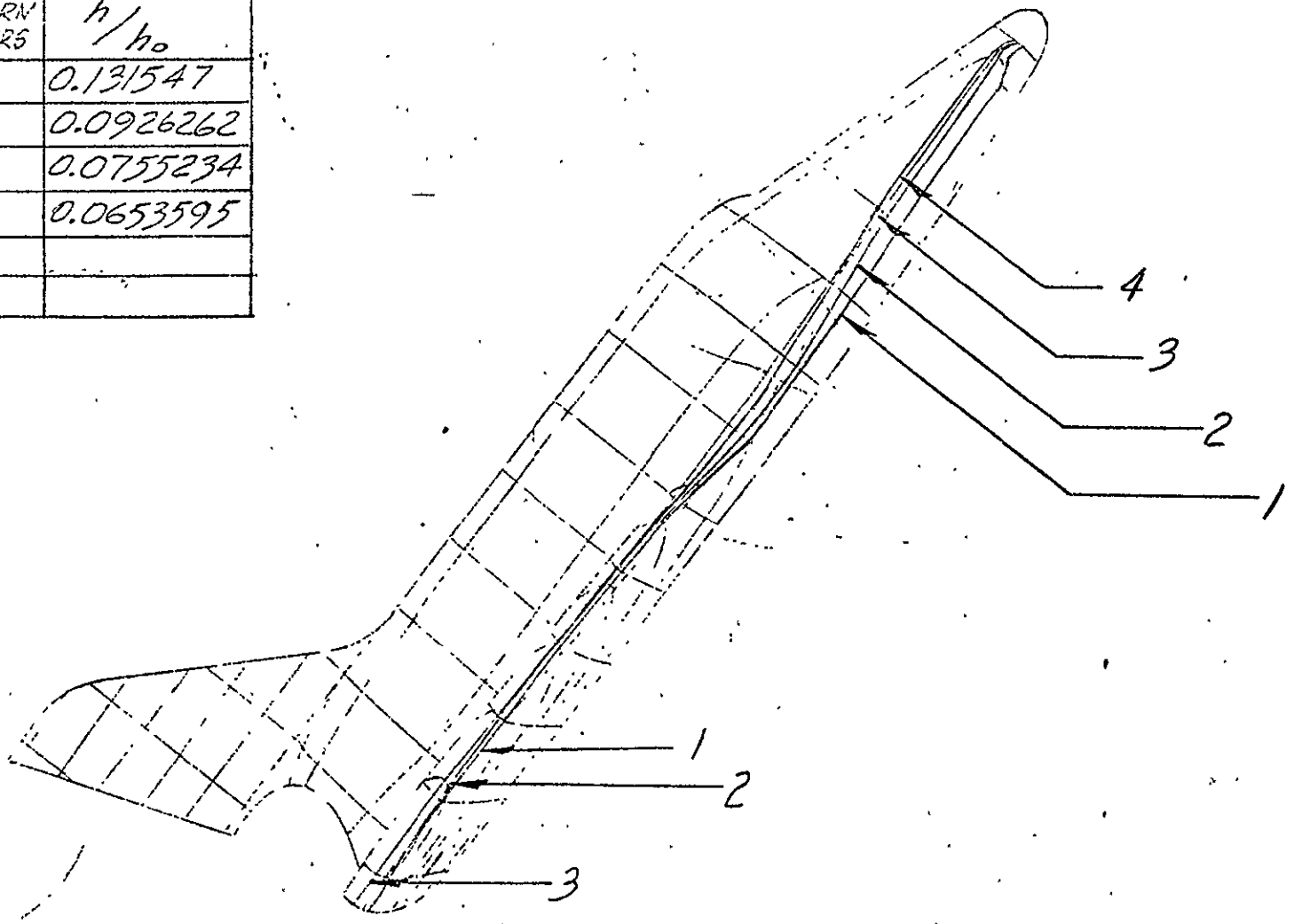
| WET AREA NUMBER | n/h ₀ |
|-----------------|------------------|
| 1 | 0.0394093 |
| 2 | 0.0277493 |
| 3 | 0.0226255 |
| 4 | 0.0195806 |
| 5 | |
| 6 | |



PHASE CHANGE COATING TEST RUN SHEET

TEST NUMBER: GFHT-017 TEST RUN NUMBER: - 019

| ISOTHERM NUMBERS | h/h_0 |
|------------------|-----------|
| 1 | 0.131547 |
| 2 | 0.0926262 |
| 3 | 0.0755234 |
| 4 | 0.0653595 |
| 5 | |
| 6 | |

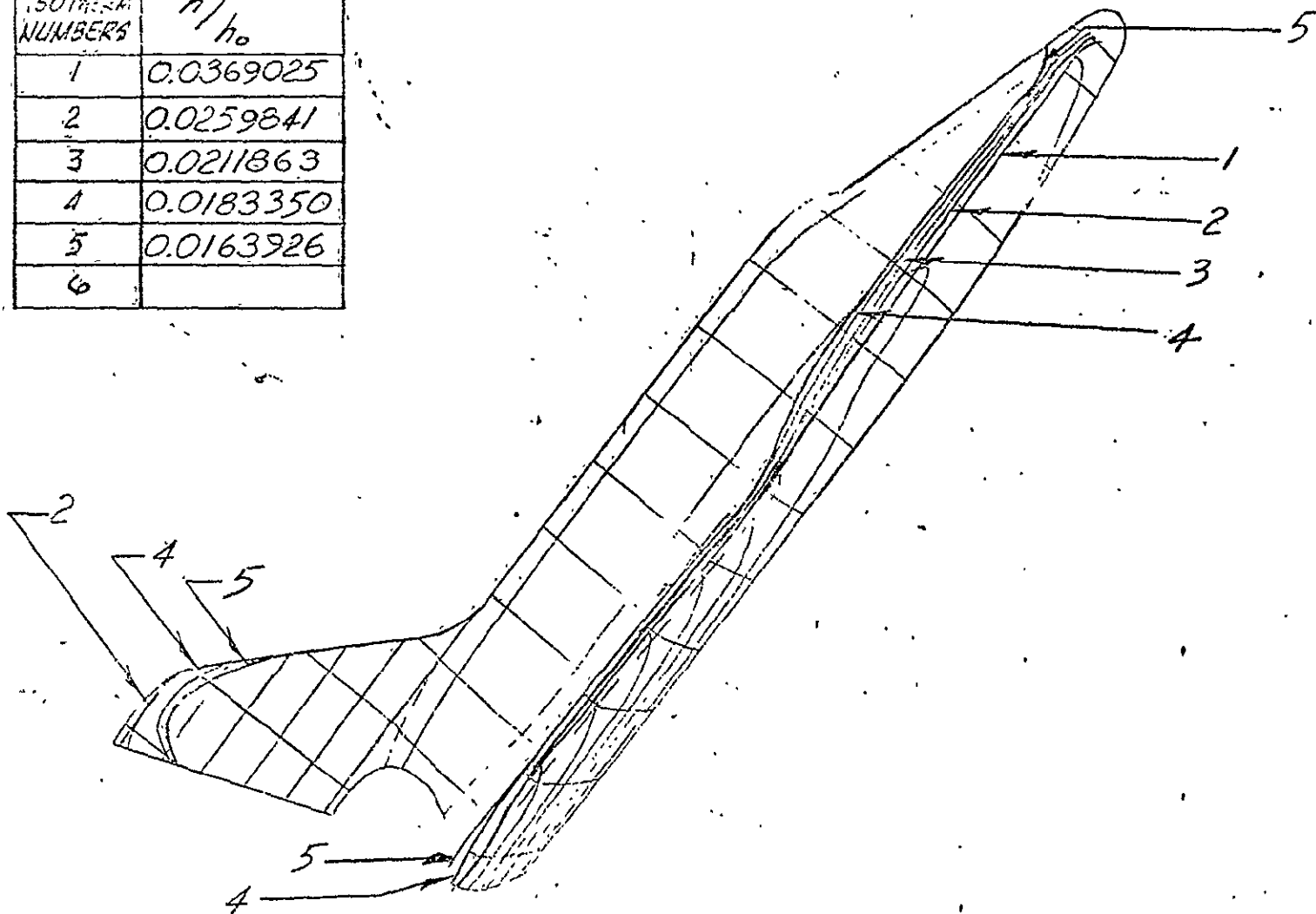


PHASE CHANGE COATING TEST RUN SHEET

TEST NUMBER: GFHT-017

TEST RUN NUMBER: 020

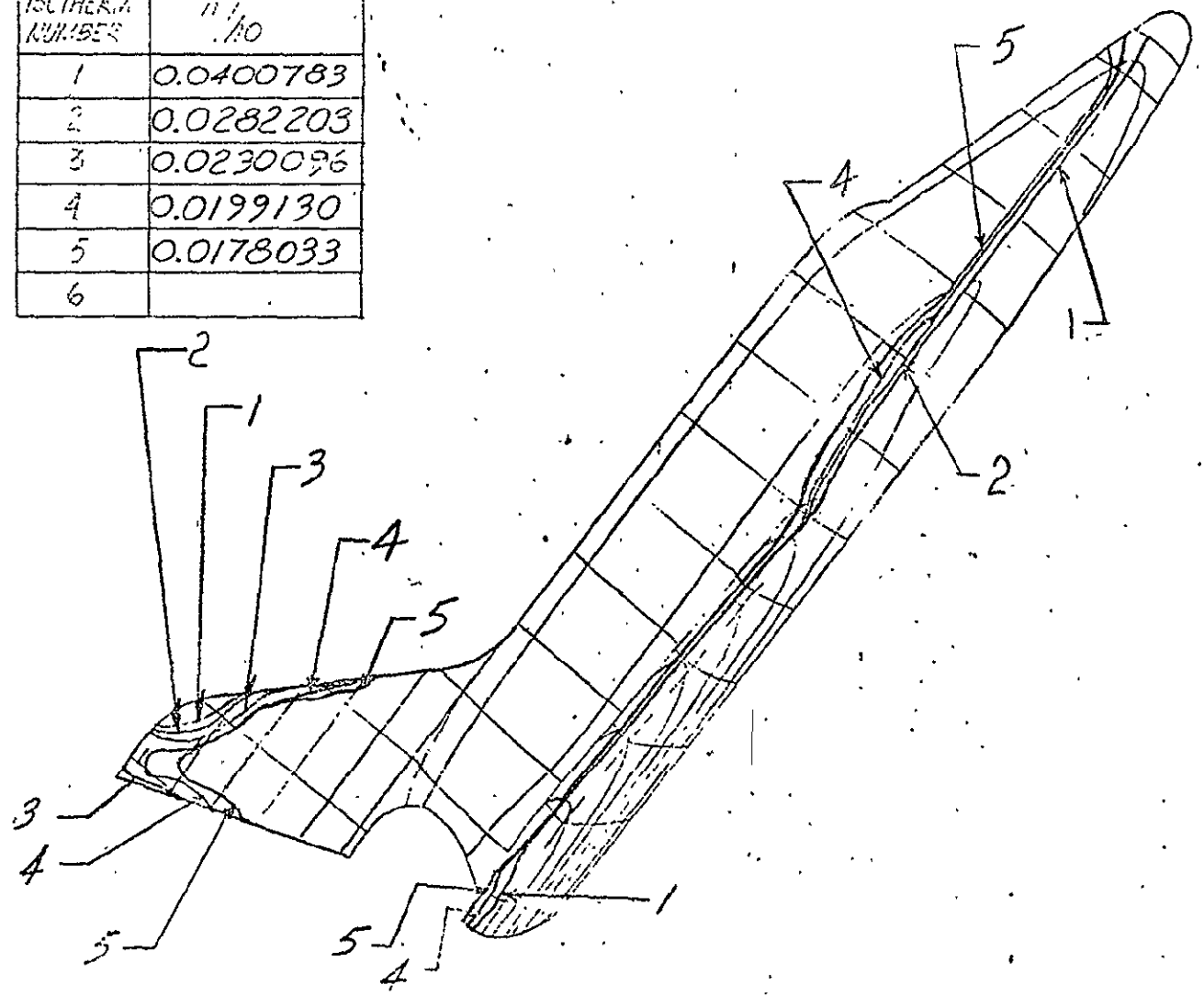
| ISOTHERM NUMBERS | h/h_0 |
|------------------|-----------|
| 1 | 0.0369025 |
| 2 | 0.0259841 |
| 3 | 0.0211863 |
| 4 | 0.0183350 |
| 5 | 0.0163926 |
| 6 | |



PHASE CHANGE COATING TEST RUN SHEET

TEST NUMBER: GFHT-017 TEST RUN NUMBER: 021

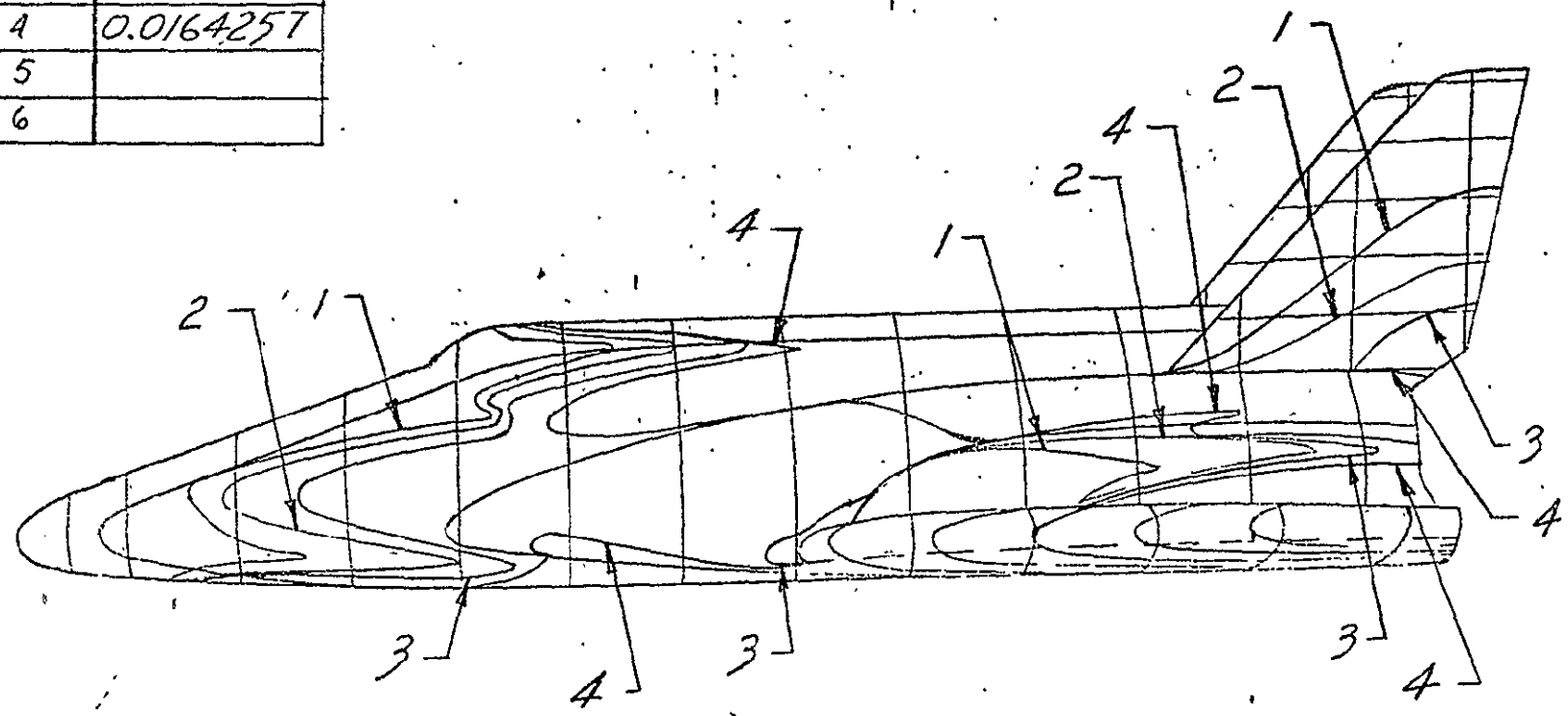
| ISOTHERM NUMBER | TIME |
|-----------------|-----------|
| 1 | 0.0400783 |
| 2 | 0.0282203 |
| 3 | 0.0230096 |
| 4 | 0.0199130 |
| 5 | 0.0178033 |
| 6 | |



PHASE CHANGE COATING TEST RUN SHEET

TEST NUMBER: GFHT-017 TEST RUN NUMBER: 031

| ISOTHERM NUMBERS | h/h_0 |
|------------------|-----------|
| 1 | 0.0330595 |
| 2 | 0.0232782 |
| 3 | 0.0189800 |
| 4 | 0.0164257 |
| 5 | |
| 6 | |

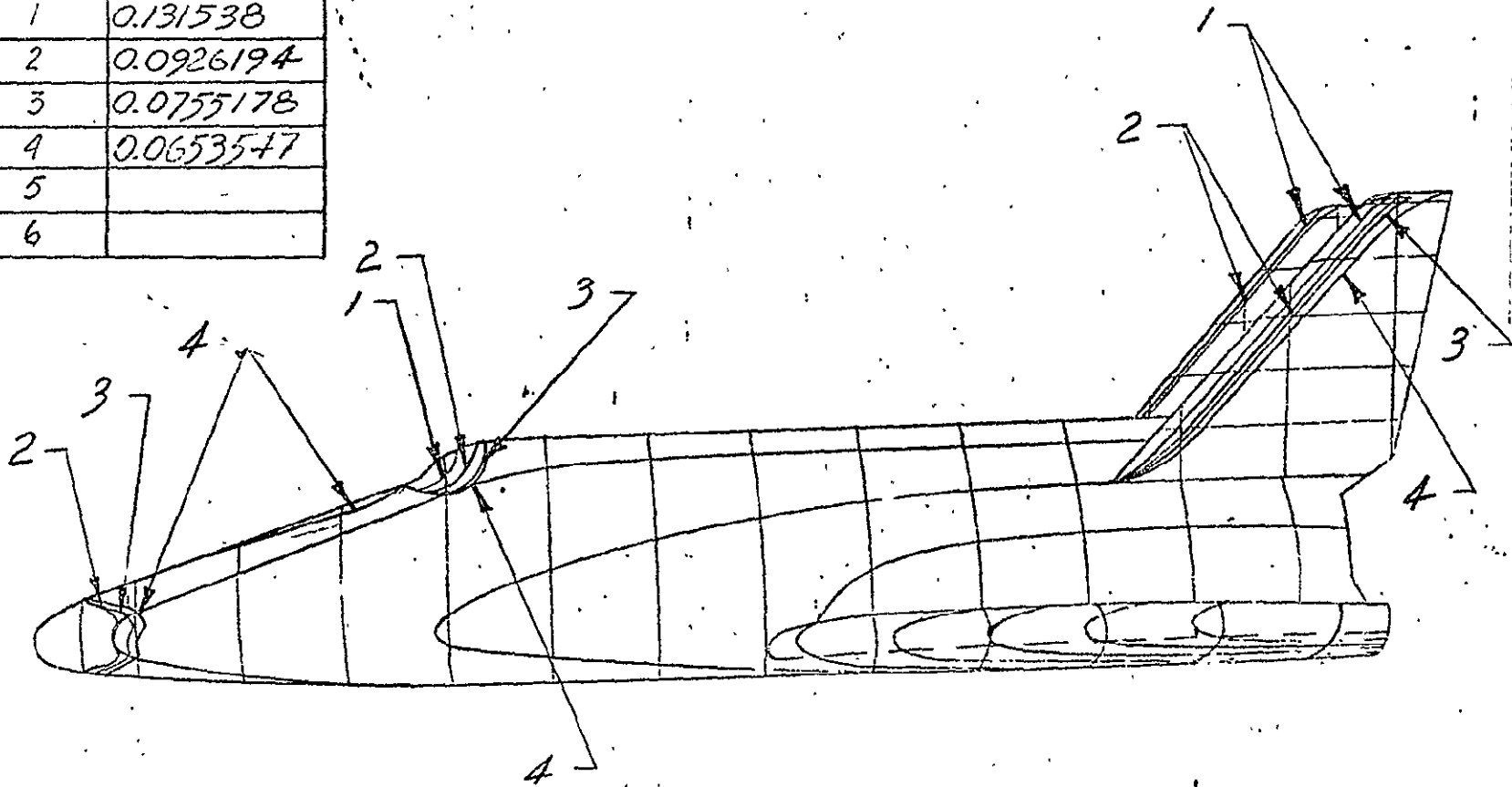


PHASE CHANGE COATING TEST RUN SHEET

TEST NUMBER: GFHT-017

TEST RUN NUMBER: 030

| ISOTHERM NUMBERS | η/η_0 |
|---------------------|---------------|
| 1 | 0.131538 |
| 2 | 0.0926194 |
| 3 | 0.0755178 |
| 4 | 0.0653547 |
| 5 | |
| 6 | |

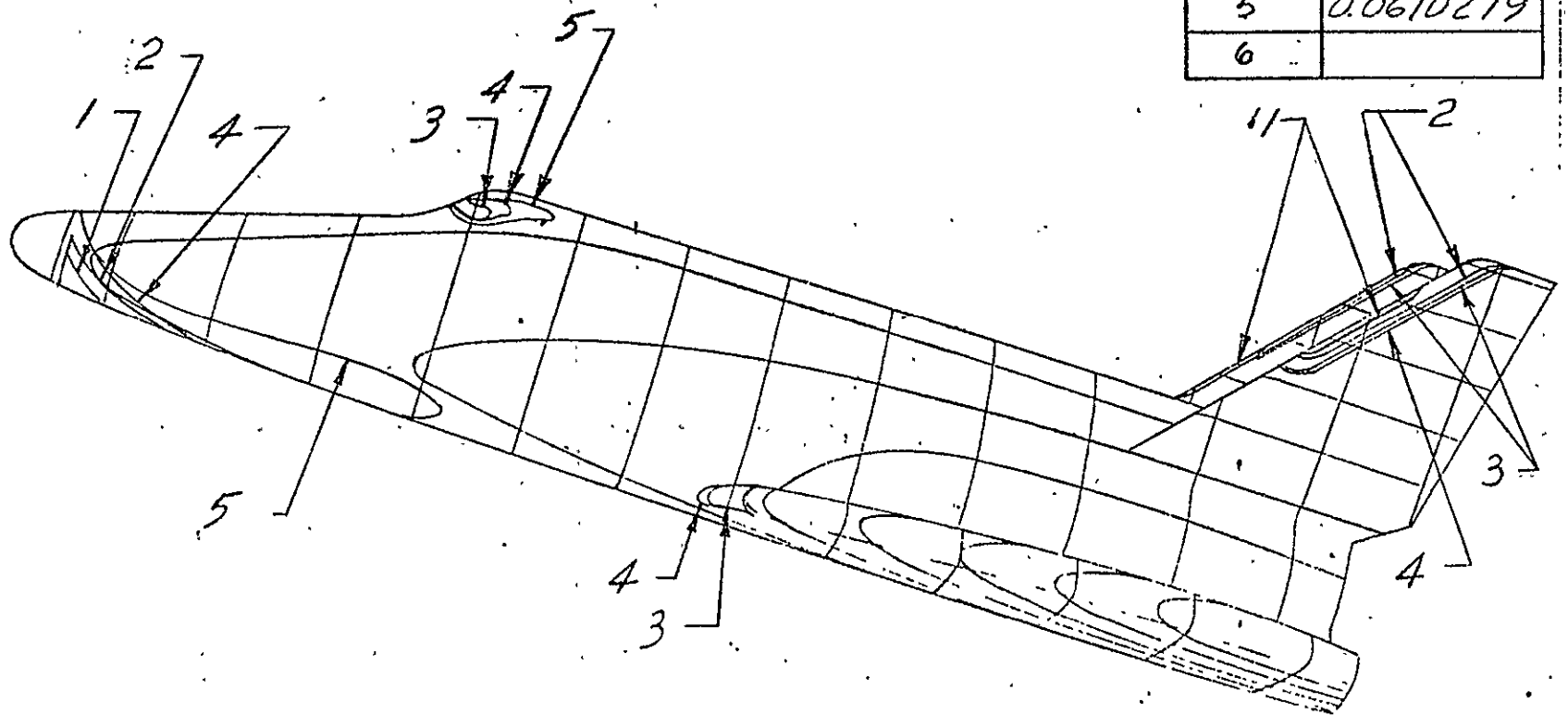


PHASE CHANGE COATING TEST RUN SHEET

TEST NUMBER: GFHT-017

TEST RUN NUMBER: 029

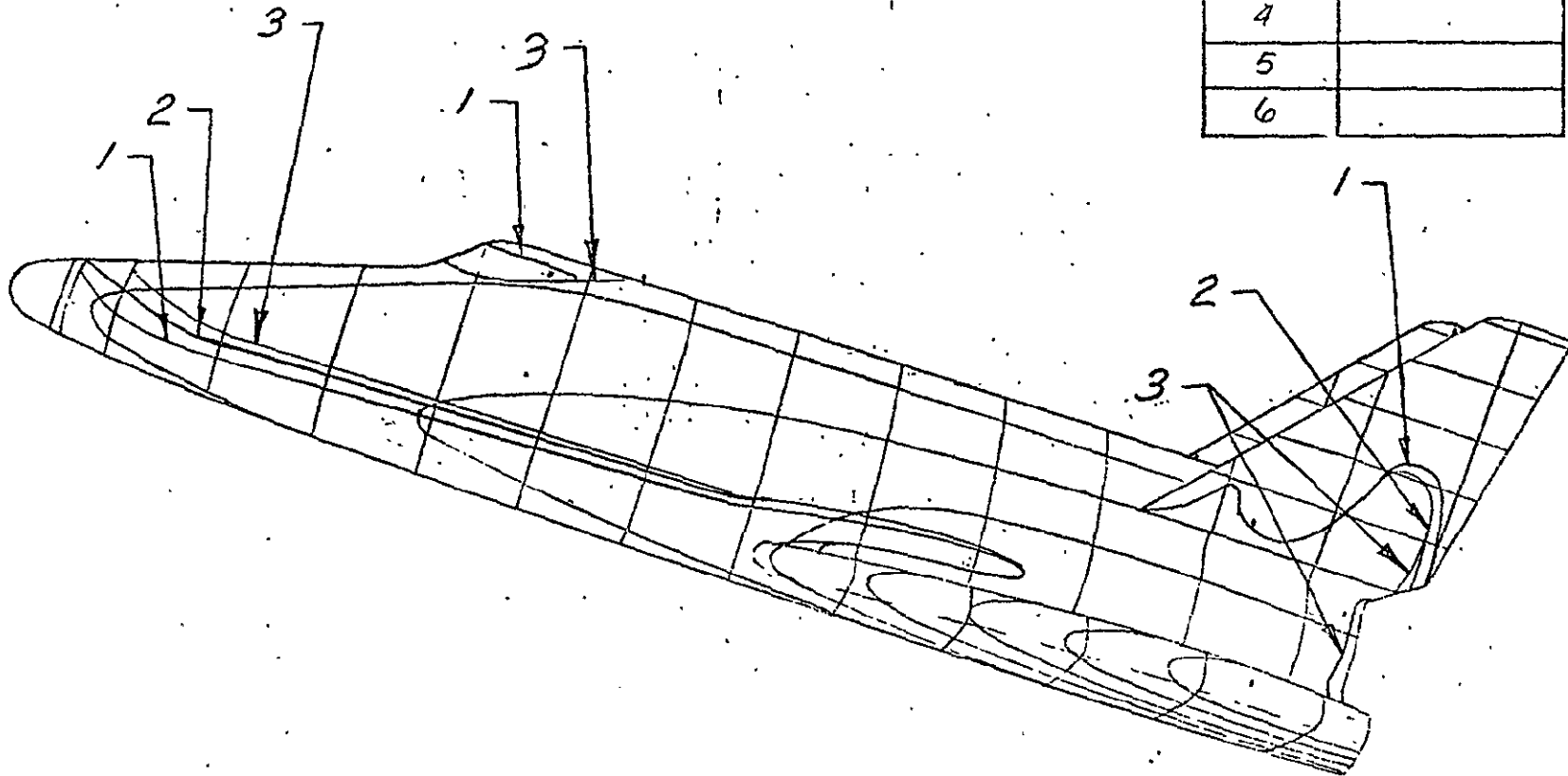
| ISOTHERM NUMBER | h/h_0 |
|-----------------|-----------|
| 1 | 0.137364 |
| 2 | 0.0967361 |
| 3 | 0.0788744 |
| 4 | 0.0682595 |
| 5 | 0.0610279 |
| 6 | |



PHASE CHANGE COATING TEST RUN SHEET

TEST NUMBER: GFHT-017 TEST RUN NUMBER: 028

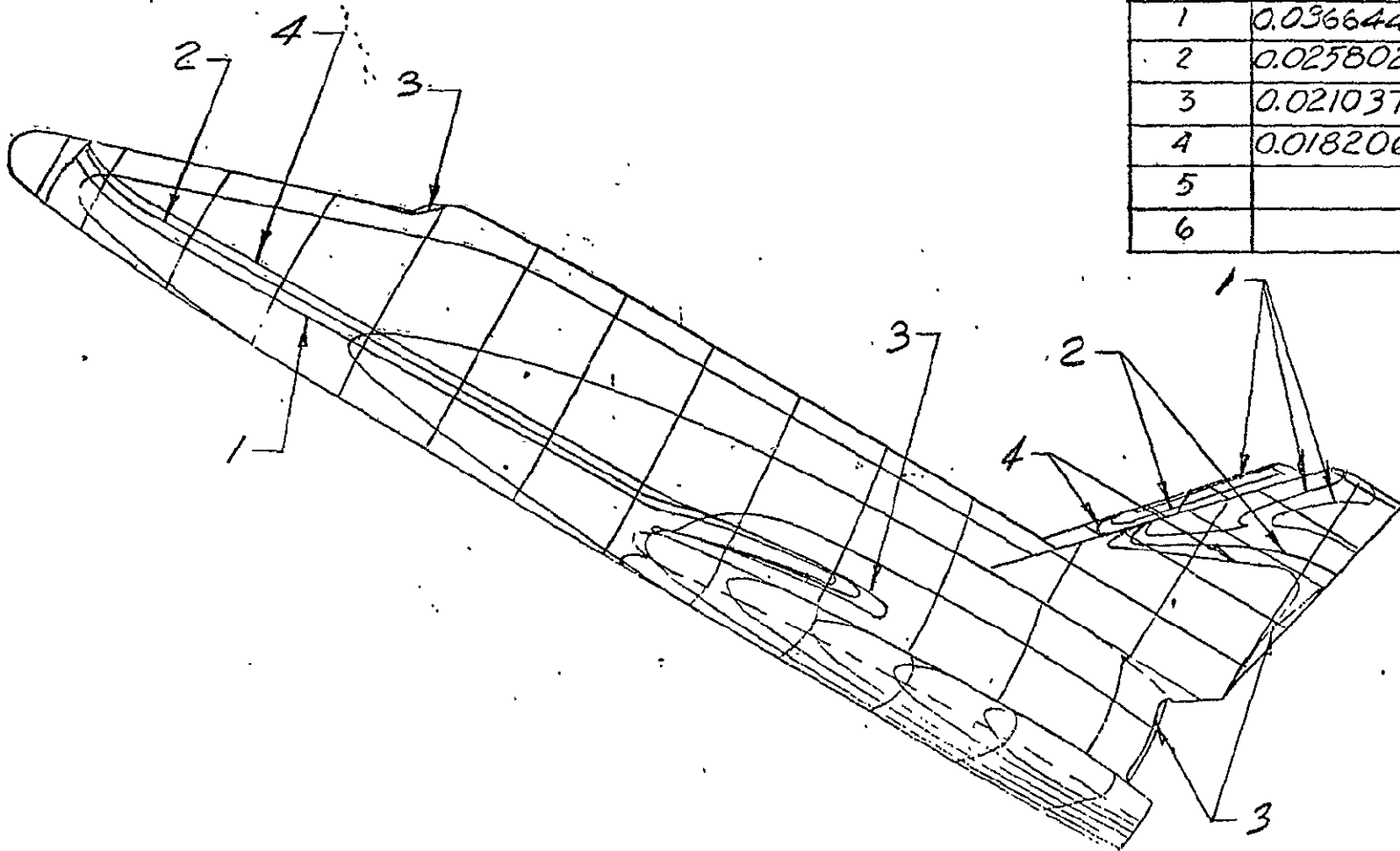
| ISOTHERM NUMBERS | h/h_0 |
|---------------------|-----------|
| 1 | 0.0396476 |
| 2 | 0.0279170 |
| 3 | 0.0183979 |
| 4 | |
| 5 | |
| 6 | |



PHASE CHANGE COATING TEST RUN SHEET

TEST NUMBER: GFHT-017 - TEST RUN NUMBER: 026

| ISOOTHERM NUMBERS | h/h_0 |
|----------------------|-----------|
| 1 | 0.0366440 |
| 2 | 0.0258021 |
| 3 | 0.0210379 |
| 4 | 0.0182067 |
| 5 | |
| 6 | |

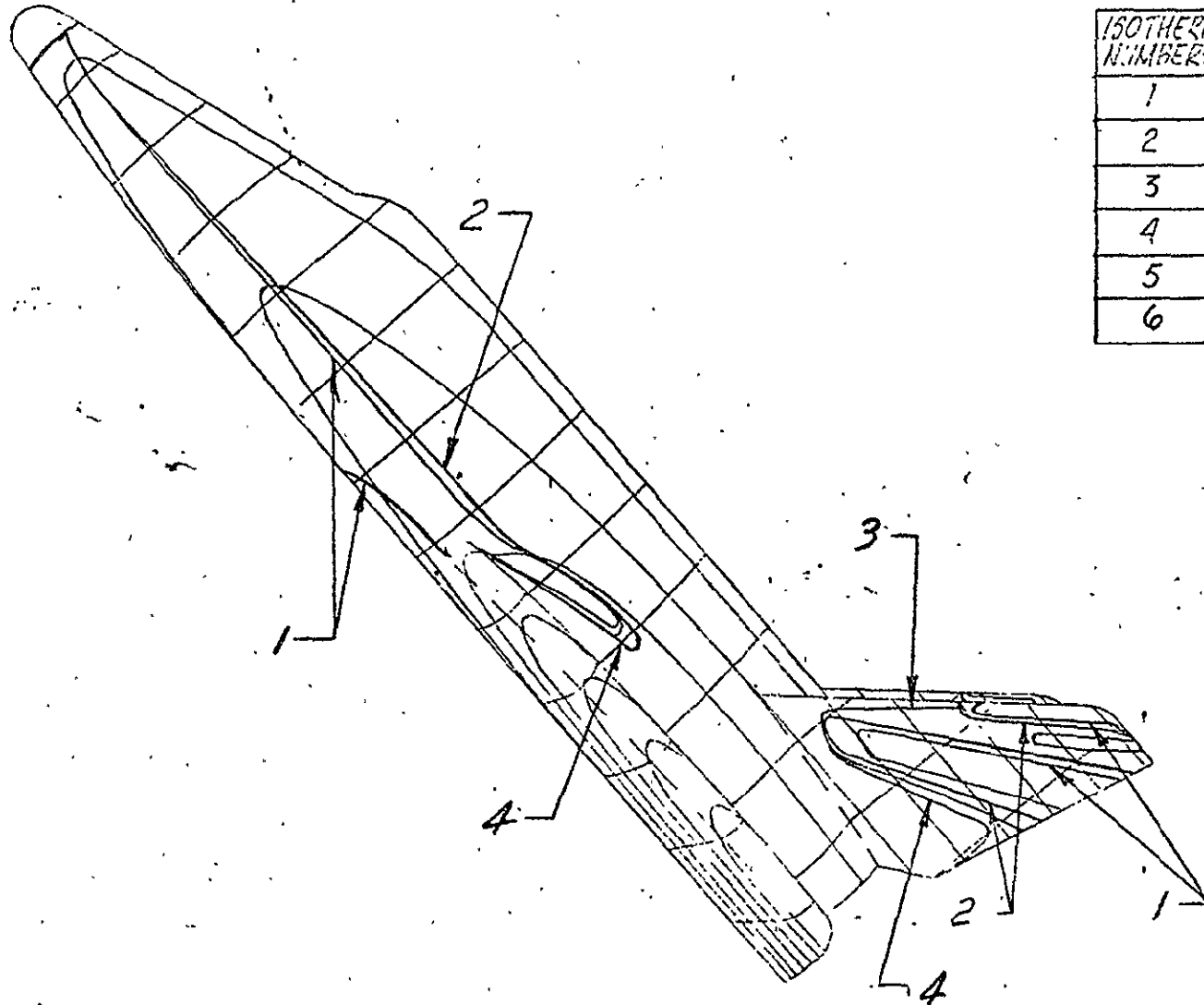


PHASE CHANGE COATING TEST RUN SHEET

TEST NUMBER: GFHT-017

TEST RUN NUMBER: 024

| ISOTHERM NUMBERS | h/h_0 |
|---------------------|-----------|
| 1 | 0.0367381 |
| 2 | 0.0258684 |
| 3 | 0.0210919 |
| 4 | 0.0182534 |
| 5 | |
| 6 | |

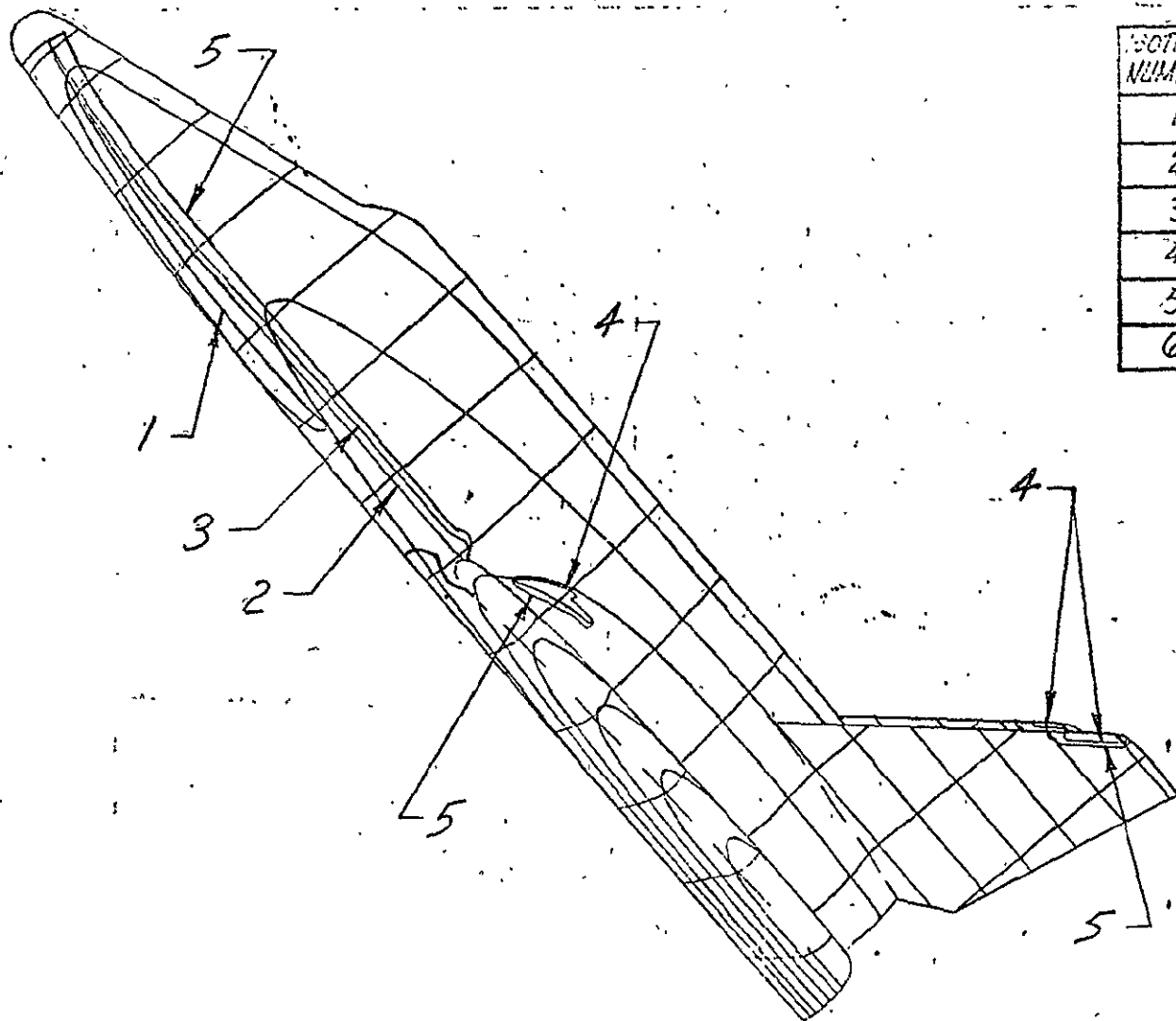


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PHASE CHANGE COATING TEST RUN SHEET

TEST NUMBER: GFHT-017 TEST RUN NUMBER: 023

| ISOTHERM NUMBERS | h/h_0 |
|------------------|-----------|
| 1 | 0.140578 |
| 2 | 0.0989850 |
| 3 | 0.0807081 |
| 4 | 0.0698465 |
| 5 | 0.0624467 |
| 6 | |



PHASE CHANGE COATING TEST RUN SHEET

TEST NUMBER: GFHT-017 TEST RUN NUMBER: - 022

