The Marquardt Corp
Van Nuys, Cal.
Sudden Expansion Burner
Mar 21, 1963
M 5.03 50000 cm ft.

FOUNDATIONAL RESEARCH PROJECT NO. 16

# A STUDY OF SUPERSONIC COMBUSTION

PRINCIPAL INVESTIGATOR: JOHN R. FACEY

INVESTIGATOR'S BACKGROUND

EDUCATION

GRADUATED FROM GEORGIA INSTITUTE OF TECHNOLOGY IN JUNE, 1963 WITH DEGREE OF BACHELOR OF AEROSPACE ENGINEERING (CUM LAUDE).

CURRENTLY ENROLLED AT PRINCETON UNIVERSITY IN THE GRADUATE PROGRAM--WORKING TOWARD DEGREE MASTER OF SCIENCE IN AEROSPACE ENGINEERING.

AWARDS

GUGGENHEIM FELLOWSHIP 1964 TO 1965 (PRINCETON UNIVERSITY).

EXPERIENCE

EMPLOYED AT THE U. S. NAVAL AIR TURBINE TEST STATION SINCE GRADUATION FROM GEORGIA TECH. CURRENTLY AEROSPACE ENGINEER (PROPULSION AND POWER) (GS-861-11). ASSOCIATED WITH PROJECTS ON ANTI-ICE SYSTEM EVALUATION, EXHAUST NOZZLE EVALUATION AND SMOKE-ABATEMENT TESTS, ON VARIOUS MODELS OF THE J79 ENGINE.

PROJECT BACKGROUND

1. INITIATED AS MASTER'S DEGREE THESIS PROJECT AT PRINCETON UNIVERSITY, WITH DR. IRVIN GLASSMAN AS ADVISOR.

2. TECHNICAL DIRECTOR OF THE AERONAUTICAL TURBINE LABORATORY, DR. JOSEPH S. DIRENDE, EXPRESSED AN INTEREST IN THE THESIS SUBJECT AS A FOUNDATIONAL RESEARCH PROJECT.

3. DR. GLASSMAN AND THE INVESTIGATOR AGREED THAT THE AREA WHICH MOST NEEDED ATTENTION WAS EXTERNAL BURNING ON AERODYNAMIC BODIES AS A MEANS OF PRODUCING THRUST. FUEL TO BE USED AT THE BEGINNING IS HYDROGEN.

## EXTERNAL BURNING

1. VARIOUS AERODYNAMIC SHAPES (PAGE 5)

2. INJECTION SCHEMES:

   A. ROUND HOLES

   B. SLOTTED HOLES

   C. PERPENDICULAR TO AIR STREAM

   D. PARALLEL TO AIR STREAM

   E. ANGLED TO AIR STREAM

3. METHOD OF IGNITION:

   A. AUTO-IGNITION

   B. PYROPHORIC FUELS

   C. SPARK

4. GAS STREAM TEMPERATURES AND PRESSURES

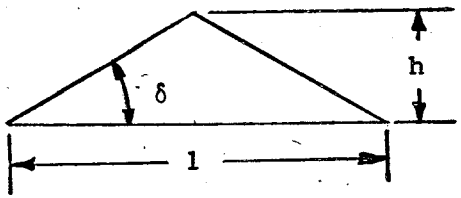
   A. $500° < T_s < 750°R$

   B. $0.566 < P_s < 1.13$ PSIA

5. FUEL TEMPERATURES AND PRESSURES

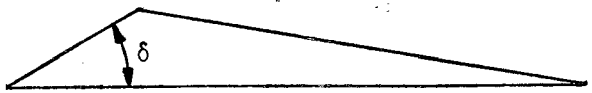
   A. $\text{AMBIENT} < T_f < 2000°R$

   B. $5.0 < P_s < 100$ PSIA



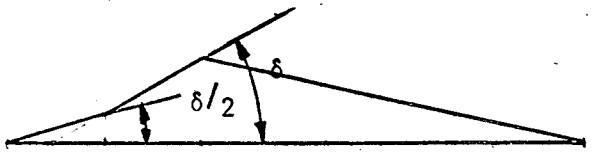

SIMPLE WEDGE

$$\frac{l}{h} = \frac{2}{\tan\delta}$$



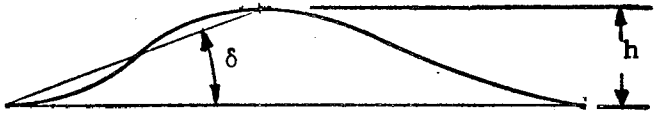

EXTENDED WEDGE

$$\frac{l}{h} = \frac{6}{\tan\delta}$$




TWO SHOCK WEDGE

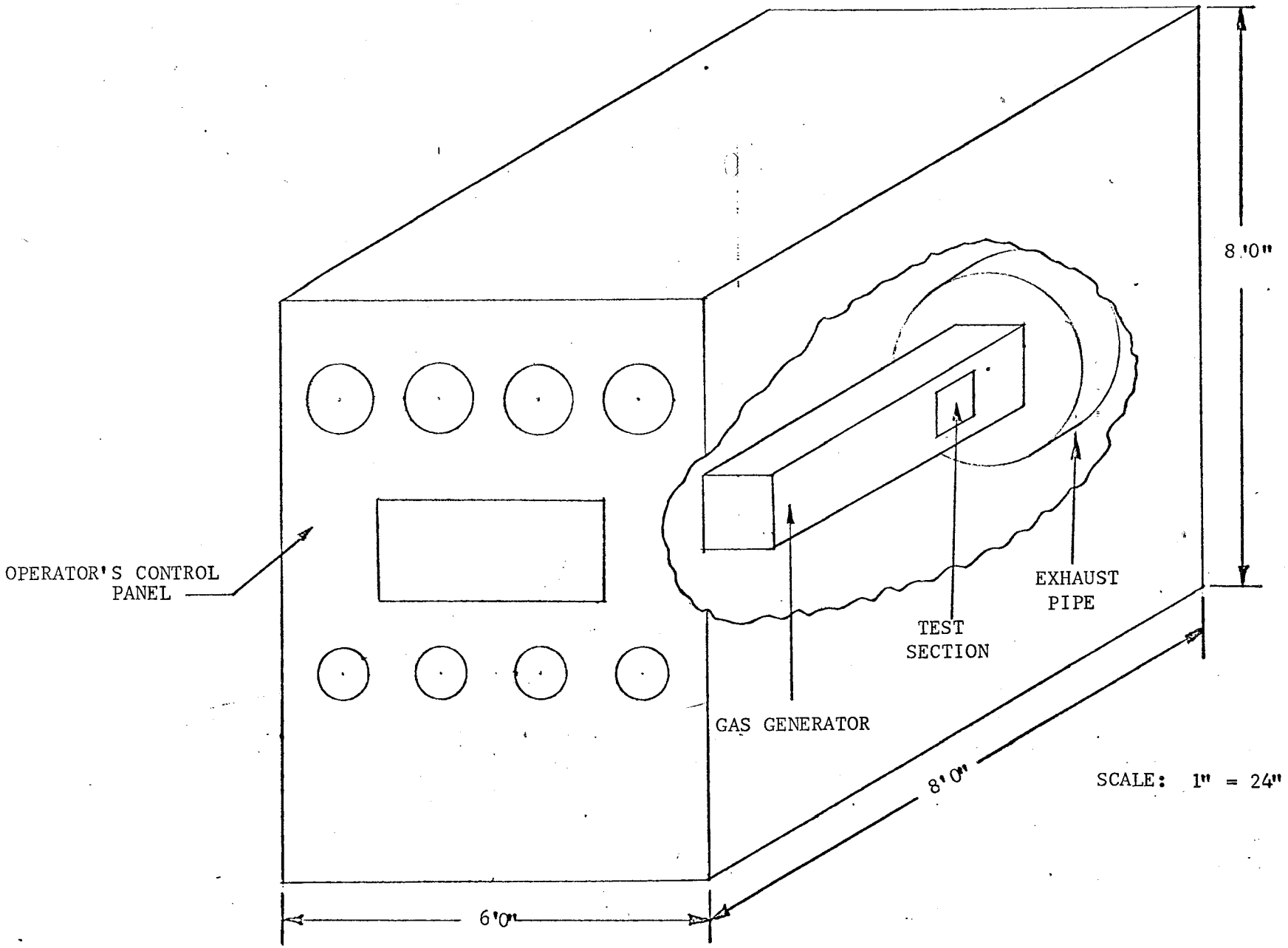
$$\frac{l}{h} = \frac{6}{\tan\delta}$$




ISENTROPIC BODY

$$\frac{l}{h} = \frac{6}{\tan\delta}$$

AERODYNAMIC SHAPES FOR EXTERNAL BURNING




ENCLOSURE FOR GAS GENERATOR AND TEST SECTION

## GAS GENERATOR

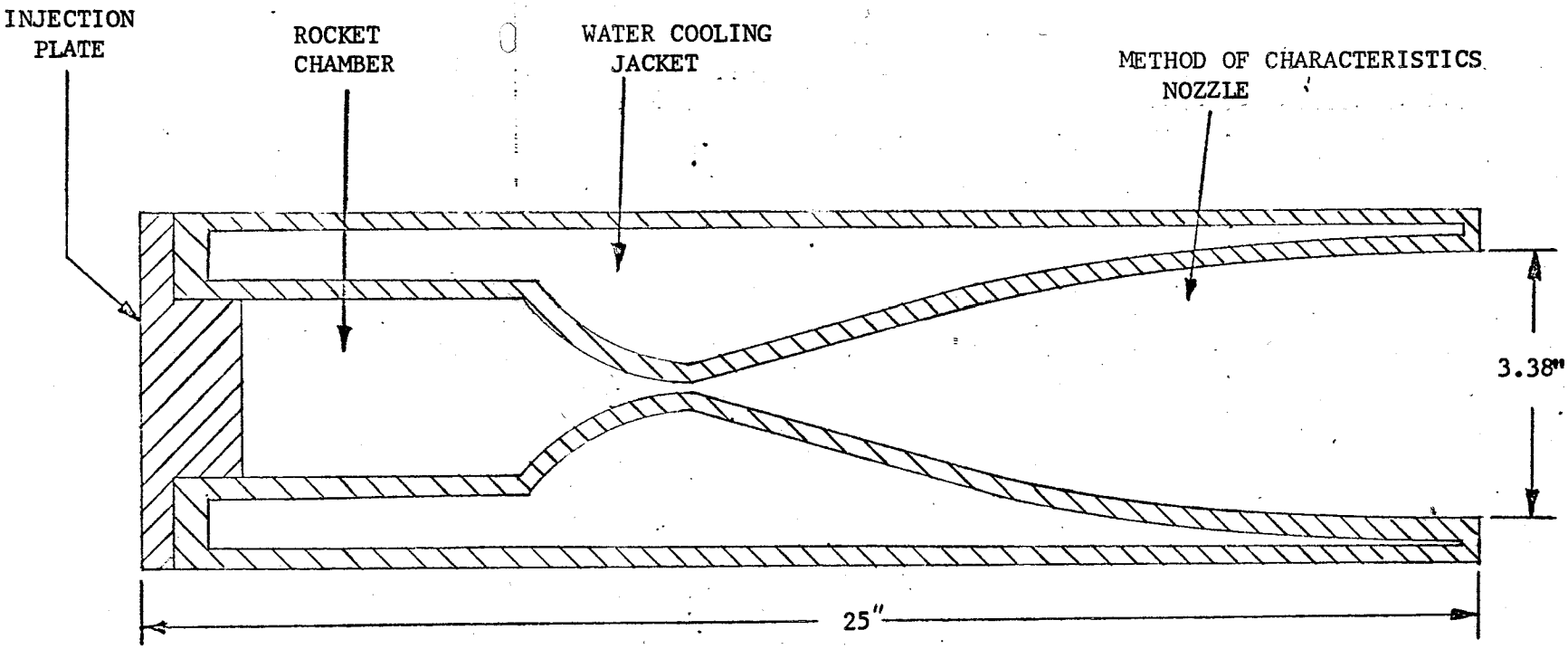
TYPE: TWO-DIMENSIONAL, WATER COOLED

GASES: $H_2$ - $O_2$ - AIR

MASS FLOW: 0.5 - 1.0 LB/SEC

PRESSURE RANGE: 300 - 600 PSIA

TEMPERATURE RANGE: 3000 - 4500°R




SCALE: 1" = 2"

MAT: S.S. 304

GAS GENERATOR SCHEMATIC

## TEST SECTION

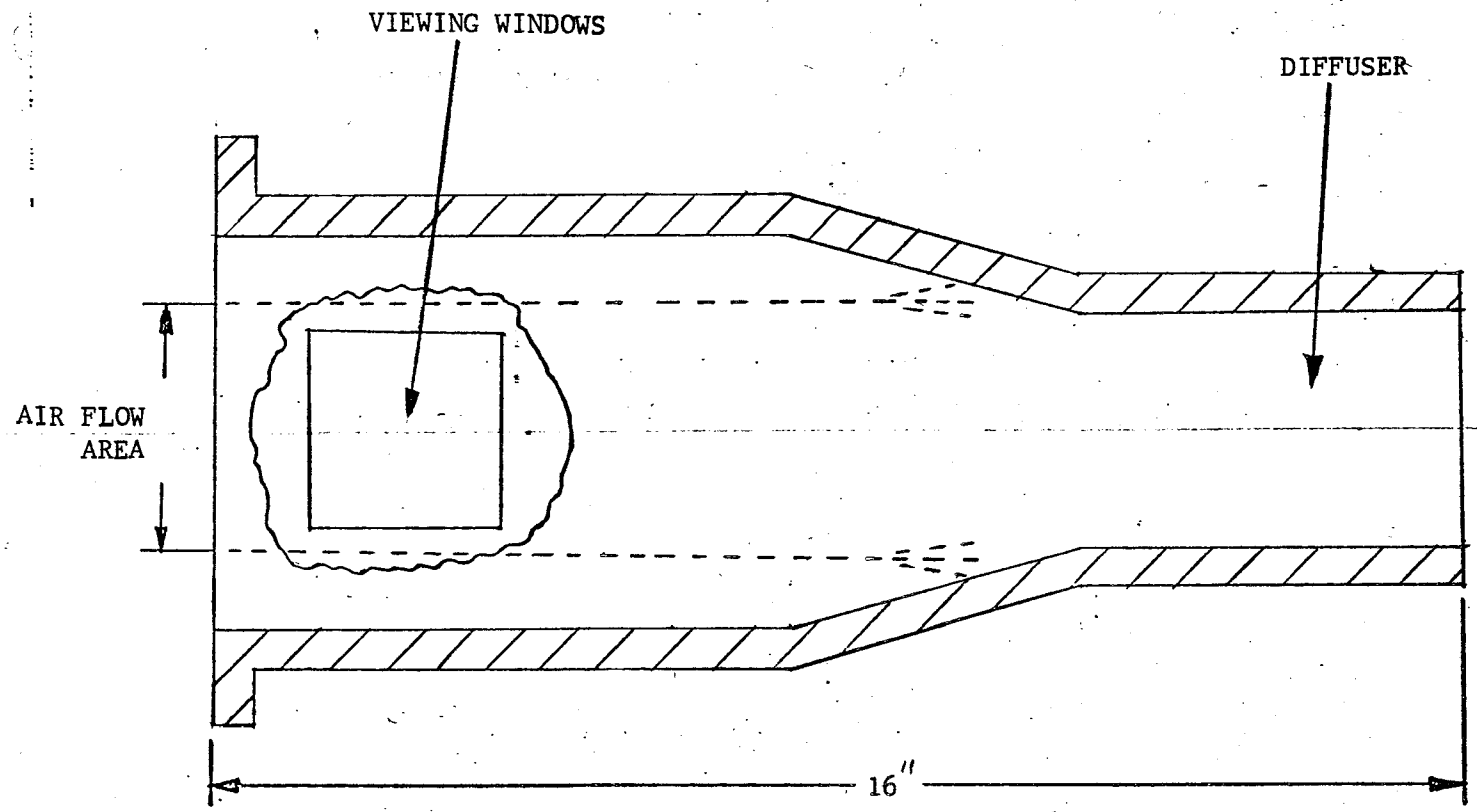
TYPE: ENCLOSED FREE-JET - TWO-DIMENSIONAL - DESIGNED FOR MOTION PICTURE AND SCHLIEREN PHOTOGRAPHY

STATIC TEMPERATURE: 500 - 750°R

MACH NUMBER: M = 5

STATIC PRESSURE: 0.566 - 1.13 PSIA

SIZE: 3.38 X 1.5 INCHES




SCALE: 1" = 2"

MAT: S.S. 304

TEST SECTION SCHEMATIC

## PARAMETERS TO BE MEASURED

1. IGNITION RANGES OF HYDROGEN
2. IGNITION AND REACTION TIME OF HYDROGEN
3. OPTIMUM INJECTION CONFIGURATIONS
4. OPTIMUM AERODYNAMIC SHAPE
5. OPTIMUM FUEL TEMPERATURES
6. PERFORMANCE ESTIMATES
7. HEAT RELEASE
8. DESIRABILITY OF VITIATED AIR TESTING
9. HEAT TRANSFER RATES IN GAS GENERATOR NOZZLE

## APPLICATION OF TEST RESULTS

1. PROPULSION (ALL OR PARTIAL) OF HIGH SPEED AIRCRAFT ($M > 3$)
2. METHOD FOR CONTROL OF HIGH SPEED AND HIGH ALTITUDE AIRCRAFT (ALT. > 80,000 FT)
3. METHOD OF CONTROL FOR MISSILES WHILE IN ATMOSPHERE

## FUTURE PLANS

1. PRESENT GAS GENERATOR

   A. DIFFERENT FUELS

      (1) HYDROCARBONS

      (2) PYROPHORIC FUELS

   B. INLET STUDIES

2. AXISYMMETRIC GAS GENERATOR

   A. IGNITION TESTING OF DIFFERENT FUELS

   B. REACTION RATES OF DIFFERENT FUELS

   C. HEAT RELEASE AT VARIOUS MACH NUMBERS

## COST ESTIMATE

1. PHASE I - $37,000

   A. MATERIAL $15,000

   B. LABOR 20,000

   C. GASES 2,000

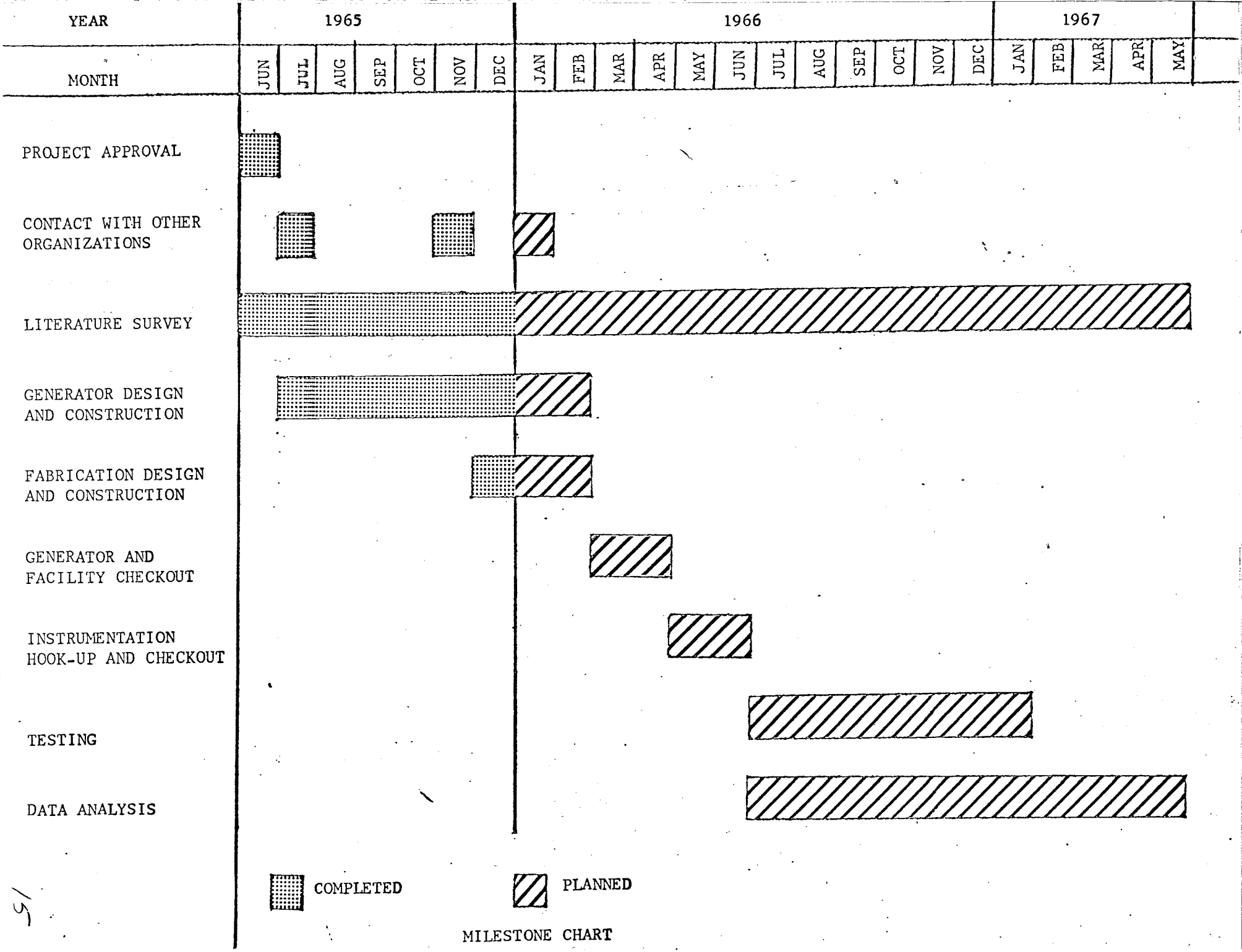
2. FISCAL YEAR EXPENDITURES

   A. 1966 $20,000

   B. 1967 17,000

3. FUELS TESTING $5,000 - 10,000

4. AXISYMMETRIC NOZZLE - $5,000




MILESTONE CHART