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AN EXPERIMENTAL INVESTIGATION OF THE FLOW IN
A PLANE WALL JET WITH AN INITIAL GAP

A THESIS

Submitted to the Faculty of Graduate Studies through
the Department of Mechanical Engineering in Partial
Fulfillment of the Requirements for the Degree
of Master of Applied Science at the
University of Windsor

by

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1965

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SUMMARY

The flow in a two dimensional plane wall jet with different initial gaps between the nozzle exit and the leading edge of the wall was probed at various stations along the jet. The jet slot thickness and the velocity were kept constant. It was found that the region close to the leading edge of the wall behaved like a transition zone. In this zone, the type of flow changed from a free jet to a wall jet. The length required for transition, which depended directly on the gap size, was so short for small gaps, that the gap effects were found to be negligible. In addition it was found that the inner layer velocity distribution of a wall jet did not follow the classic one-seventh power law.

ACKNOWLEDGEMENTS

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NOTATION

x coordinate along the jet from the nozzle exit.

x_o value of x where maximum velocity begins to decay.

x' non-dimensional distance, i.e., $\frac{x}{t}$

y coordinate normal to the center line of the free jet or

           normal to the wall of the wall jet.

y_m value of y at maximum velocity point

$y_{m/2}$ value (larger one for the wall jet) of y at one half of

           maximum velocity point.

t thickness of the nozzle exit

a constant defined by Eq. (2.6)

b constant defined by Eq. (2.6)

u velocity component in the x - direction

u_m maximum velocity along the jet.

u_o initial jet velocity (at nozzle exit).

v velocity component in the y - direction

σ constant defined by Eq. (2.3)

α disposable constant in Glauert's theory (Ref.5)

τ_o Shear stress along the wall of the wall jet.

ρ density of the air.

ν kinematic viscosity.

R Reynolds number

ϵ eddy viscosity

LIST OF FIGURES

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CHAPTER I

INTRODUCTION

Information obtained from the study of a wall jet would be useful in the field of blown-flaps in which a thin jet is blown over the top surface of a flap to prevent flow separation. In such a high-lift device there is usually a gap between the lip of the jet nozzle and the leading edge of the flap.

In all of the experimental and theoretical investigations of wall jet flow (Refs. 3 to 9) the flow surfaces considered were attached to the nozzle with no intervening gap. A possible exception to the above statement is the work reported in Ref. 12, in which the Coanda effect at deflection surfaces detached from the jet nozzle was studied by force measurements. However, no results of flow measurement in a wall jet with an initial gap have been found.

The present investigation aims to provide information on the flow in a plane wall jet in still air with an initial gap. Since this is a preliminary study of the gap effect, curvature of the wall surface and the speed of the surrounding air are not considered.

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CHAPTER II

LITERATURE SURVEY

The material covered in this section summarizes
briefly the existing literature and is included in the report for
the sake of completeness and ease of reference. The present in-
vestigation of the gap effect on the wall jet requires not only a
knowledge of the wall jet itself, but also information on the
"free-jet" bridging the gap between the nozzle exit and the leading
edge of the wall. A literature survey on the free jet was initiated
to obtain this information. This information is especially important
when the gap is very large and allows a free jet to exist in the
region of the gap.

2. 1 FREE JET

A two dimensional free jet is obtained by a flow
emerging from a smooth nozzle with a large contraction ratio and
spreading into still air between two end plates. Due to the mixing
effect with the surrounding air, the central core of uniform velocity
gradually diminishes downstream from the nozzle exit, the jet width
growing and the maximum velocity along the center-line of the jet
decreasing. (See Fig.1).

Prandtl (Ref.1) first gave a dimensional analysis of
the free jet. He assumed that the static pressure throughout the
jet was substantially equal to that of the surroundings and the jet
momentum remained constant downstream. He proved that the velocity

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at the centre of the jet was proportional to $x^{-1/2}$, that the jet width

was proportional to x and that the mean velocity profiles were similar

along the jet.

Gortler used Prandtl's mixing length theory (Ref.2),
i.e., the eddy viscosity is constant across the jet at each distance
from the nozzle exit and is proportional to the product of the maximum
velocity and the width of the jet.

He started with the basic boundary layer equation,

$$u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} = \epsilon\frac{\partial^2 u}{\partial y^2} \tag{2.1}$$

and the boundary condition:

$$y=0: \quad u=v=0; \quad y=\infty: \quad u=v=0$$

$$y=y_m: \quad \frac{\partial u}{\partial y} = 0 \tag{2.2}$$

With the application of Prandtl's mixing length theory (Ref.2) for
the eddy vixcosity, ϵ, and proper integration of equation (2.1.), his
final equation for the velocity distribution is:

$$u = u_m \text{ sech}^2 \left(\frac{0.88y}{y_{m/2}}\right) = u_m \text{ sech}^2 \left(\frac{\sigma y}{x}\right) \tag{2.3}$$

Where σ is a constant determined by experiment.

Borque (Ref.3) gave his measurements of $\sigma = 12$
near the nozzle exit and decreasing to about 7.5 for large x' values.
Reichardt (Ref.3) and Forthmann (Ref.4) found from their measurements
that $\sigma = 7.67$ for large x' values.

2.2. WALL JET

A jet flowing over a solid surface is called a wall
jet. (see Fig. 2). In 1934, Forthmann (Ref.4) first presented the
results of his measurements made on a wall jet. He found that:

$$u_m \propto x^{-1/2} \quad \text{and} \quad y_{m/2} \propto x^{0.997} \qquad (2.4)$$

His logarithmic plot of the velocity versus the distance normal to the
wall in a region close to the wall (inner layer, see Fig.2) indicated
that $u \propto y^{1/7}$. Further, he found that the form of the velocity
distribution across the jet remained unchanged, i.e., the velocity
profiles were similar.

Nearly twenty years after Forthmann's experiments,
in 1956, Glauert (Ref.5) presented a theoretical analysis of the
wall jet problem. He used Prandtls' hypothesis (Ref.2) for the outer
layer (see Fig. 2) of the wall jet and Blasius' shear stress formula
(Ref.2) in the inner layer:

$$\frac{\tau_o}{\rho} = 0.0225 \ u^2 \ (\frac{\nu}{uy})^{1/4} \qquad (2.5)$$

This equation gave a 1/7th power law for the velocity in the inner
layer.

For the wall jet, Glauert determined that $u_m \propto x^a$
and $y_{m/2} \propto x^b$ where:

$$a = \frac{-\alpha(\ 9 + 8\alpha \ )}{2(5+9\alpha +4\alpha^2)}$$

$$b = \frac{(9+8\alpha \ )}{2(5+4\alpha \ )} \qquad (2.6)$$

The constant α in the above equation is to be determined experimentally.

He also stated that since the layer of the wall jet was governed by Blasius' formula (Ref.2) and the outer layer by Prandtl's hypothesis (Ref.2), complete similarity was no longer possible.

In 1958, Sigalla (Ref.6) obtained $\alpha = 1.2$ from his measurements made on the velocity profiles for a Reynolds number of 6.2×10^4. By evaluating Glauerts' expression - see equation (2.6) - for $\alpha = 1.2$ the following results were obtained:

$$a = -0.517 \quad \text{and} \quad b = 0.95 \qquad (2.7)$$

These were in slight disagreement with his experimental results which were $a = -0.500$ and $b = 1.00$ $\qquad (2.8)$

He also found that the numerical constant in Blasius' formula, equation (2.5), was 0.0283 instead of 0.0225 for Reynolds numbers up to 10^5. The central core velocity was observed to remain constant for about 10 nozzle widths from exit.

In reference 7, published in 1961, Schwarz and Cosart presented their results from hot wire anemometer measurements for Reynolds numbers ranging from 2.2×10^4 to 10.6×10^4:

$$a = -0.555 \text{ and } b = 1.00 \qquad (2.9)$$

The most important finding of their experiments was that the velocity in the inner layer varied approximately as the $1/14$ th power of the normal distance from the wall. This result entirely disagreed with the power-law of $1/7$ which was found by Forthmann (Ref.4) and used as an assumption by Glauert (Ref. 5) in his theoretical analysis.

This disagreement is due to the modification of the structure of the inner layer of the wall jet by the turbulence in the outer layer. As a result of the difference in the power-law, the skin-friction coefficient of a wall jet varies in a manner different from that of a turbulent boundary layer.

Myers, Schauer and Eustis (Ref.8) substantiated the results of Schwarz and Cosart that the inner layer velocity profile had a power-law close to 1/14. They also stated that the constants were

$$a = -\,0.49 \pm 0.03 \quad \text{and } b = 0.95 \pm 0.03 \quad (2.10)$$

In addition, the length of the central core of uniform velocity ranged from 4 to 14 nozzle widths.

Recently, Gartshore and Hawaleshka (Ref.9) found the inner layer velocity of a wall jet to follow a power law of 1/11.4 for values of x' > 18 and the constants were:

$$\alpha = 1.2, \quad a = 0.53 \quad \text{and} \quad b = 1 \quad (2.11)$$

for a value of x' > 38 downstream of the jet.

CHAPTER III

TEST FACILITIES

A schemetic diagram of the test facilities is shown in Fig. 4. References to the letter code used in Fig. 4 are made in the description of the test facilities.

3.1 AIR SUPPLY AND GUIDING DUCT

Air was supplied by a type HS, size 200 American Standard centrifugal fan (A) with static pressure of 5 inches water. This fan was driven by a 5 hp, 1745 rpm General Electric induction motor. A 30 inch long, wooden guiding duct (B) with a rectangular cross section was attached to the fan exit. A honey - comb flow straigthener was placed in the guiding duct to reduce the turbulence level induced by the fan.

3.2 CONTRACTION DUCT AND NOZZLE

A wooden contraction duct (C) 30 inches long was placed after the guiding duct. A converging nozzle (D) made of brass with a 0.25" X 9" exit was attached to the contraction duct. The contraction ratios for the nozzle together with the duct were 62:1 in the direction of 0.25" width and 2.5:1 in the perpendicular direction. A Kiel probe with a 0.125" - diameter shroud was placed in the contraction duct to measure air supply pressure.

3.3 WALL AND TRAVERSING MECHANISM

The wall (E) consisted of a piece of 18"x 9" x 0.25" acryllic plastic sheet and was mounted perpendicular to the end - plates with the 9" direction being parallel to the spanwise (9" length) direction

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of the jet slot.

A piece of 30" x 9" x 0.25" acryllic plastic plate was mounted on the top of the wall. This plastic plate and a piece of cold rolled steel plate of the same size, which was placed at the bottom of the wall, were used as end-plates to obtain a two - dimensional flow condition. The traversing mechanism (F), used for moving the wall to the required gap position, was capable of moving the wall both parallel and perpendicular to the jet. In both the directions, distances could be measured to an accuracy of 0.005" with a full range up to 8 inches. The traversing mechanism was provided with leveling screws to ensure correct alignment with the nozzle exit.

3.4 PROBING EQUIPMENT

A flattened stainless steel hypodermic tube with an opening of 0.005" x 0.060" was used to measure the total pressure in the jet. This probe was mounted on a specially designed apparatus which enabled the probe to have three dimensional movement with an accuracy of ±0.001 inch. A mulitube inclined manometer with an accuracy of ± 0.025 inch of water was utilized in making all pressure measurements.

CHAPTER IV

EXPERIMENTS

The principal objective of the experiments was to determine
the effect of an initial gap on the flow in a plane wall   jet. Studies
were made of the similarity of the velocity profiles, the jet growth
and the maximum   velocity decay. Probing of the jet sheet at various
stations along its length was, therefore, the first experiments under-
taken. Such probings at mid - span position were carried out for the
free jet and the wall jet with and without a gap. The nozzle width
and the jet velocity at the nozzle exit were kept constant during the
test program. The size of the gap was the important variable.

4.1 CALIBRATION

The flattened hypodermic tube used for measuring
the total pressure was compared with a small Kiel probe under actual
test conditions. The results indicated a very good agreement.

Velocity distributions across the width of the nozzle
exit at different positions along the span of the nozzle were determined.
No significant changes in these distributions were noted. The velocity
distribution was found to be effectively uniform over 85% of the 0.25"
width varying only $\pm 1\%$ from the central - core velocity of 140 ft/sec.
A velocity profile taken at mid - span is shown in Fig. 5. Frequent
repeatability checks were also carried out during the experimentation.

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4.2 TEST PROCEDURE

4.2.1 FREE JET

The two end plates were attached to the nozzle exit. The two - dimensional free jet was probed at nine different station ($10 \leqslant x' \leqslant 46$) downstream from the nozzle exit. The total pressure probe was traversed across the jet in steps of 0.050" except near the maximum velocity point where steps of 0.025" were used.

The probings were also useful in determing the jet efflux angle. It was found that the jet direction was along the centre line of the nozzle.

4.2.2 WALL JET

The wall was installed between the two end plates and the leading edge was sealed against the nozzle exit. The two - dimensional plane wall jet was then probed at six different stations along the wall ($10 \leqslant x' \leqslant 70$)... In the inner layer (see Fig. 2) the probe was traversed across the jet in steps of 0.001" while in the outer layer the step distance was 0.005". A correction for the effective center (Ref. 10) was applied to the readings taken close to the wall.

By means of the traversing mechanism the wall was moved away from the nozzle exit. The different gaps were obtained by moving the wall in the following ways:

1. directly outward from the zero gap position parallel to the axis of the free jet (gaps indicated by G_1, G_2, G_3, and G_4 in Fig. 3).

2. along the approximate boundary of the free jet (determined by the point where the velocity was 5 % of the maximum velocity)

but still keeping the wall parallel to the centre line of the free
jet (gaps shown as G_a, G_b, G_c, G_d and G_e in Fig. 3).

The jet sheet flow over the wall was then probed at
three locations ($x' = 22$, 46 and 70) in the same way as the wall
jet with no gap. For gaps G_d and G_e, jet probing was done at four
stations.

CHAPTER V

EXPERIMENTAL RESULTS

5.1 DATA REDUCTION

The fluid was treated as incompressible because the maximum velocity of the jet was only 140 ft/sec. From barometric pressure and room temperature the density of air was determined. It was also assumed that the static pressure remained constant throughout the jet and was equal to the ambient pressure. The experimental data was reduced with the help of an IBM 1620 computer. Input data were room temperature, barometric pressure, manometer reading, x, y, and u_o. The values of u, u_m, y_m, $y_{m/2}$, $\frac{u}{u_m}$, $\frac{u_m}{u_o}$, and $(y_{m/2} - y_m)/t$ were obtained as out put information.

5.2 PRESENTATION AND DISCUSSION OF RESULTS

5.2.1 FREE JET

A non - dimensional velocity profile plotted in Fig.6 shows that the experimental results agree very well with Gortler's theory over the central region - Eq. (2.3). These results confirm the experimental results of Forthmann (see Fig. 23.7 of Ref.2). The free jet growth is shown in Fig. 7. It is seen that $y_{m/2}$ increases linearly with x. The statistical method of linear regression (Ref. 11) was used to fit the best line to the free jet experimental data. The slope of the line is:

$$\frac{d}{dx'} \left(\frac{y_{m/2}}{t} \right) = 0.10 \tag{5.1}$$

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$$\frac{u_m}{u_o} = 3.42 \, (x')^{-0.49} \qquad (5.3)$$

This equation gives the empirical constant a = −0.49. The above

relation is practically the same as that given in Refs. 6 and 8.

The growth of the wall jet is shown in Fig. 12 with a plot of

$\frac{y_{m/2}}{t}$ vs x'. The best line to fit the experimental points has the

slope of

$$\frac{d}{dx'} \left(\frac{y_{m/2}}{t} \right) = 0.089 \qquad (5.4)$$

The inner layer thickness, y_m, is also found to be practically a

linear function of x' (see Fig. 17). The average value of the

ratio of $\frac{y_m}{y_{m/2}}$ is determined to be 0.165.

In the case of a free jet, the distance $y_{m/2}$ is

measured from the point of maximum velocity. But in the wall jet,

it is measured from the wall. Therefore, any growth comparison of

the two types of jet should take the difference between the two

definitions for $y_{m/2}$ into acount. In other words, it is more

reasonable to compare one half of a free jet with the outer layer of

a wall jet than with the wall jet as a whole. So the variation of

$(\frac{y_{m/2} - y_m}{t})$ along the length of the wall jet is plotted in Figures

7 and 12 and compared with that of the free jet in Fig. 7 (for free

jet, $y_m = 0$). The rate of growths of the outer layer is given by:

$$\frac{d}{dx'} \left(\frac{y_{m/2} - y_m}{t} \right) = 0.065 \qquad (5.5)$$

This gives $\sigma = 13.5$. Further, these figures show that the rate of

growth of a free jet is higher than that of the wall jet as a whole.

A log - log plot of the variation of the velocity in
the inner layer of the wall jet is shown in Fig. 13. From the
regression line with a correlation coefficient of 0.95, it is found
that for $0.02 \leqslant \frac{y}{y_{m/2}} \leqslant 0.2$, $\frac{u}{u_m}$ varies approximately as $(\frac{y}{y_{m/2}})^{1/12}$

The fact that the lower limit, 0.02, is larger than the
values presented in Refs. 7 and 8 is not due to the size of the
probe but mainly due to the dimensions of the wall and the slot.
This result substantiates the earlier findings (Refs. 7,8,
and 9) that the inner layer velocity profile has a lower power - law
than the classic value of 1/7.

5.2.3 WALL JET WITH A GAP

5.2.3.1 GAPS OBTAINED BY THE FIRST METHOD

The gaps are so small that the leading edge of the
wall is within the central core of a free jet. These small gaps do
not affect the wall jet significantly. In other words, wall jet
with such gaps have the same non - dimensional velocity profile
(see Fig. 14) and practically the same rate of jet growth and
maximum velocity decay (see Figs. 7,8, and 9) as the wall jet
without a gap.

However, it is worth noting that at any given distance
from the nozzle exit, the value of $(\frac{y_{m/2} - y_m}{t})$ is higher than, and
the value of $\frac{u_m}{u_o}$ is less than, that of the wall jet with zero gap.
This is because of the change in the initial condition of the wall
jet caused by the increased jet thickness and decreased (average)
jet velocity. The change in this initial condition depends on the
gap size. Further, in the region close to the leading edge of the

wall, the rates of jet growth and maximum velocity decay are slightly

different from those values for no gap. These differences diminish

rapidly downstream from the leading edge.

5.2.3.2 GAPS OBTAINED BY THE SECOND METHOD

The plots in Fig. 15 show dimensionless velocity

distributions across the jet at three or more stations along the

length of the wall for five different gap positions. The dotted

curve gives the non - dimensional velocity profile for the wall

jet without a gap.

These gaps, unlike the previous type, introduce

dissimilarity of the velocity profiles which is explained as follows:

In the first type of gap, the leading edge of the wall is kept in

the central core and hence there is practically no velocity gradient

just ahead of the wall. For the second type of gap, the leading

edge is at the jet boundary and a velocity gradient just upstream

of the wall is introduced.

It is interesting to note that the value of $\dfrac{y_m}{t}$

is higher than the value for the wall jet without a gap, the difference

increasing with increasing gap size (see Fig. 17). However, for

any given gap size, the difference decreases rapidly downstream from

the leading edge (also shown in Fig. 17) and finally tends towards

a constant value, i.e., the rate of change of $\dfrac{y_m}{t}$ with x' approximately

equals the zero gap rate. The shift of the maximum velocity point

is due to the effect of the wall drawing the jet closer, which is

caused by the difference in shear stresses acting in the inner and

in the outer layer.

As the gap size increases, the velocity profile in the region of the wall close to the leading edge resembles the free jet profile more than the wall jet profile (see Figs. 15d and 15e). The above point is better indicated in Fig.16 in which the velocity profiles for different gaps at fixed position ($x' = 22$) from the nozzle exit are plotted.

Maximum velocity decay for wall jets with different gaps are shown and compared with the free jet in Fig. 8. As one can intuitively expect, the decay plots for all gaps lie in between the curves for free jet and wall jet without a gap. An important point is that even though the values of u_m/u_o for any gap size is less than the no gap value, the rate of decay eventually tends towards that of a wall jet without a gap. For gaps G_c, G_d, and G_e, u_m/u_o at $x' = 22$ is closer to the free jet value than that of the wall jet with zero gap because the gap sizes are large. This figure clearly indicates that the region close to the leading edge of the wall is a transition region, where the jet changes from a free jet to a wall jet. Qualitatively stating, the length of the transition region depends directly on the size of the gap.

Plots of jet growth ($\dfrac{y_{m/2} - y_m}{t}$ vs x') for various gaps are shown and compared with free jet growth in Fig. 7b. The rate of growth of the jet changes from that of the free jet and approaches the rate of the wall jet without a gap. Unlike the decay curves (Fig. 8), the growth plots of Fig. 7b for large gaps, namely, G_c, G_d, and G_e, do not lie in between the lines for the free jet and wall jet with zero gap. This is because of the rapid shift

of the maximum velocity point in the transition region as shown in

Fig. 17.

CHAPTER VI

CONCLUSIONS

6.1 WALL JET WITHOUT A GAP

(1) Velocity profiles are similar.

(2) Non - dimensional velocity profile agrees only approximately with Glauert's theoretical profile for α = 1.2.

(3) The maximum velocity decay could be described by the following expression for $x > x_o$:

$$\frac{u_m}{u_o} = 3.42 \, (x')^{-0.49}$$

(4) Both layers of the jet are found to grow linearly with x' but with different slopes.

(5) σ for the outer layer is 13.5.

(6) The velocity - profile in the inner layer does not follow the classic one - seventh power law.

6.2 WALL JET WITH A GAP

(1) For gaps within the central core (G_1 to G_4), the effects on the wall jet flow are negligible, i.e., the dimensionless velocity profile, the rates of jet growth and maximum velocity decay and the power law of the inner layer velocity profile are all practically unchanged.

(2) The wall jet flow in a region close to the leading edge of the wall is affected by the gaps for which the wall edge is kept at the jet boundary (G_a to G_e). In this region, velocity profiles

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are not similar and the rates of the jet growth and the maximum velocity decay change from point to point along the length of the jet. Specifically, the type of flow changes from a free jet to a wall jet.

(3) The region affected by the gap could be described as a transition region, the length of which is increased by an increase of gap size.

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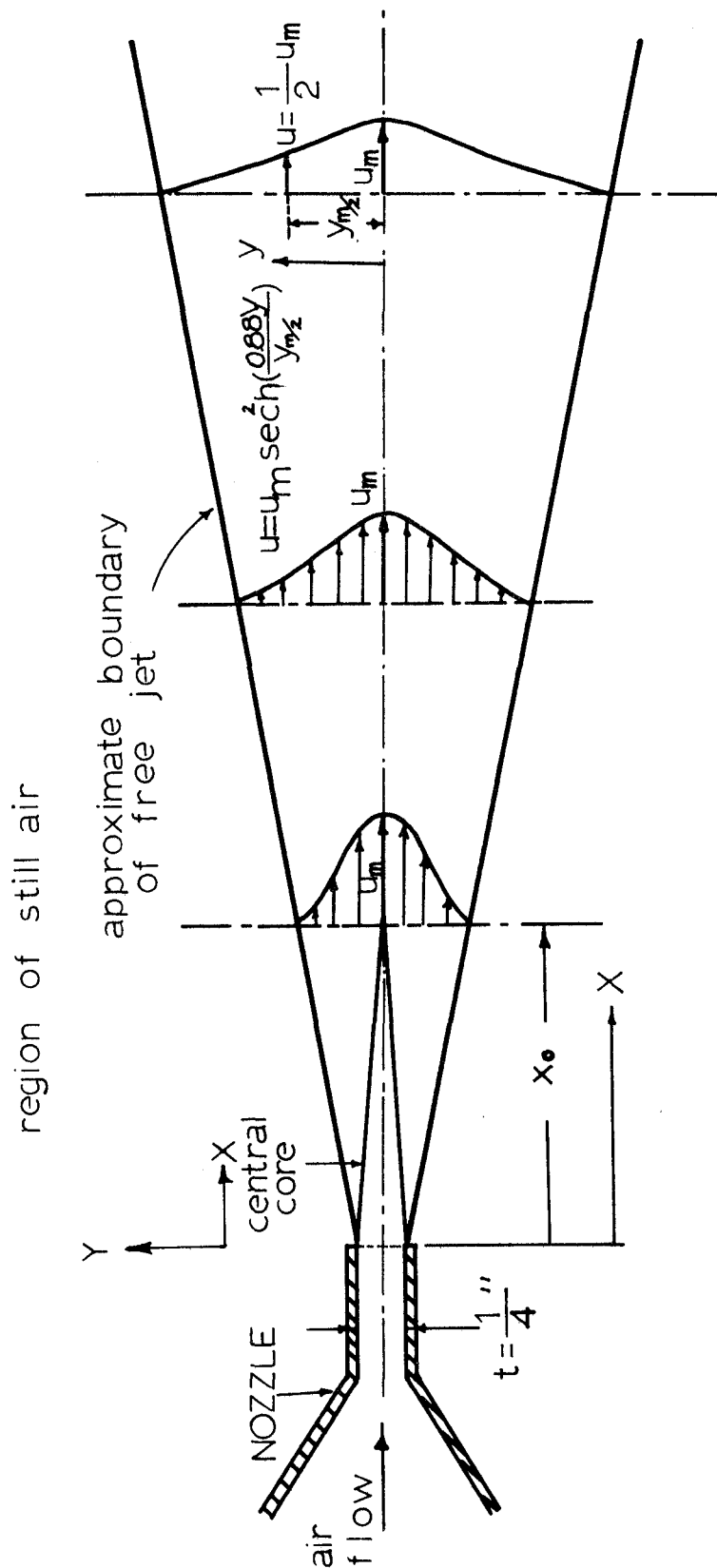   Aeronautics and Space Journal, Vol. 8 NO. 1,
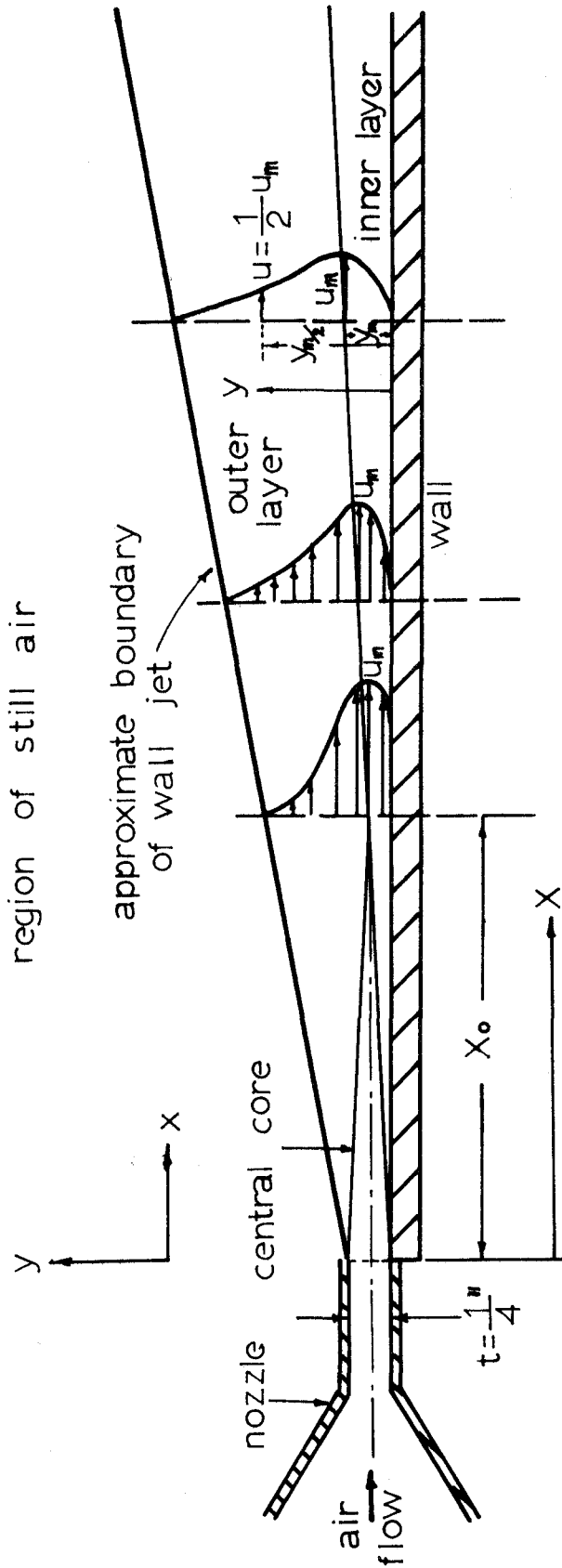   Jan.(1962)

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region of still air

approximate boundary
of free jet

$u = \frac{1}{2} u_m$

$u = u_m \operatorname{sech}^2\left(\dfrac{0.88\,y}{y_{m_{1/2}}}\right)$

$y_{m_{1/2}}$ u_m

y

u_m

u_m

central core

X
Y

NOZZLE

air flow

$t = \frac{1}{4}''$

X_o

X

Fig. 1   FREE JET NOMENCLATURE

Fig. 2   WALL JET NOMENCLATURE
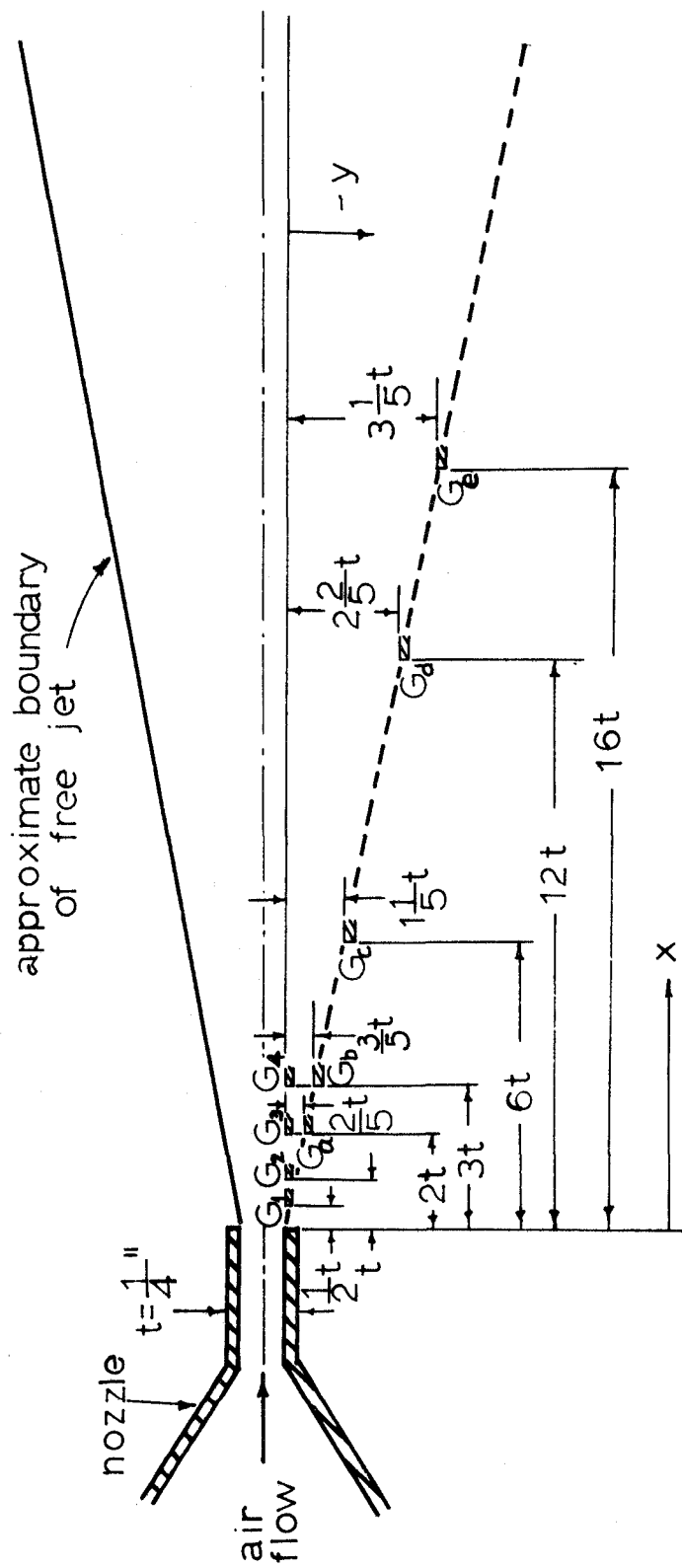
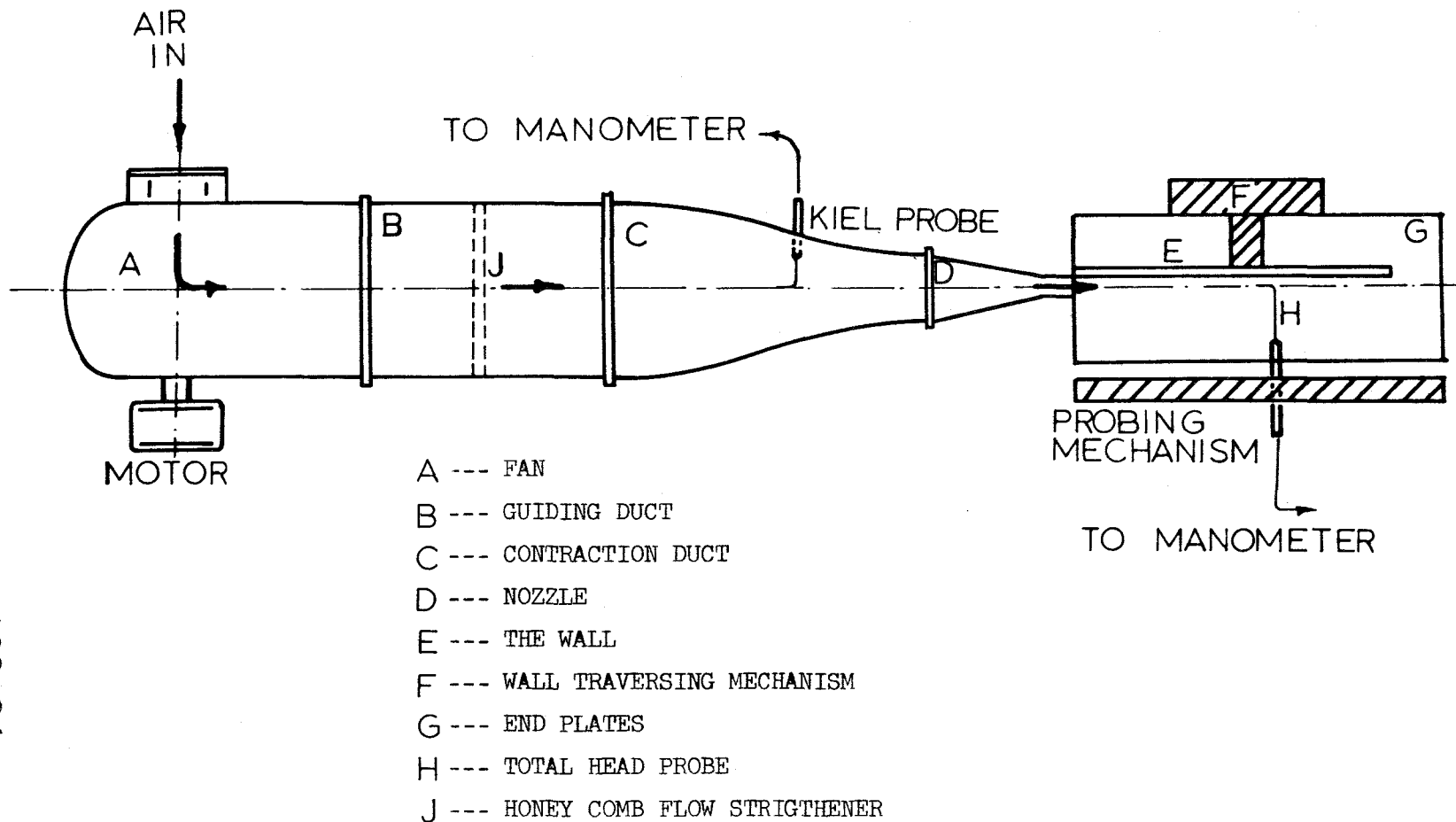Fig. 3   POSITIONS OF GAPS BETWEEN THE NOZZLE EXIT AND THE WALL

AIR IN

TO MANOMETER

KIEL PROBE

B

A

J

C

D

E

F

G

H

MOTOR

PROBING MECHANISM

TO MANOMETER

A --- FAN

B --- GUIDING DUCT

C --- CONTRACTION DUCT

D --- NOZZLE

E --- THE WALL

F --- WALL TRAVERSING MECHANISM

G --- END PLATES

H --- TOTAL HEAD PROBE

J --- HONEY COMB FLOW STRIGTHENER

Fig. 4   SCHEMATIC DIAGRAM OF TEST FACILITIES

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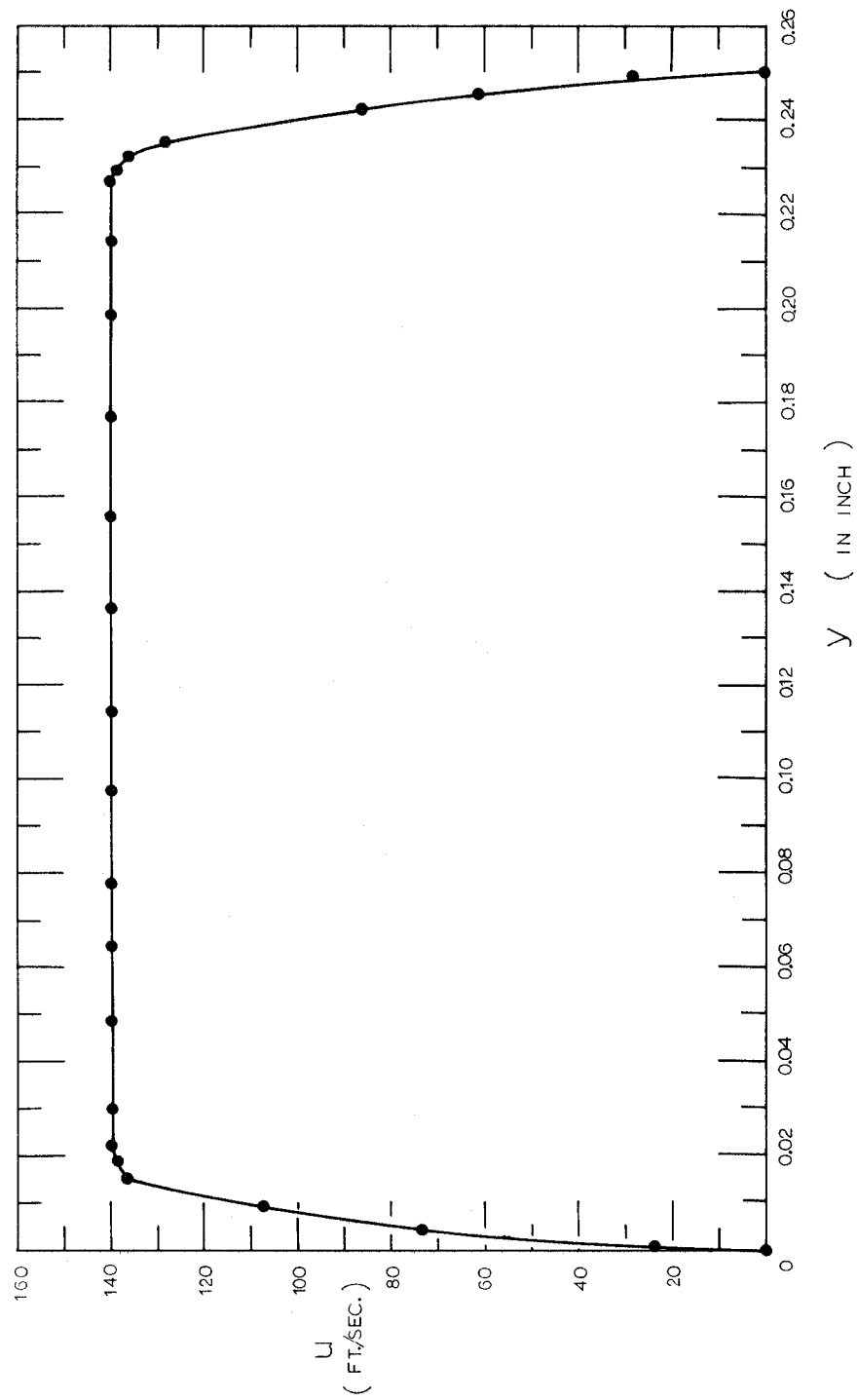
Fig. 5   VELOCITY DISTRIBUTION AT THE MID-SPAN OF THE NOZZLE EXIT
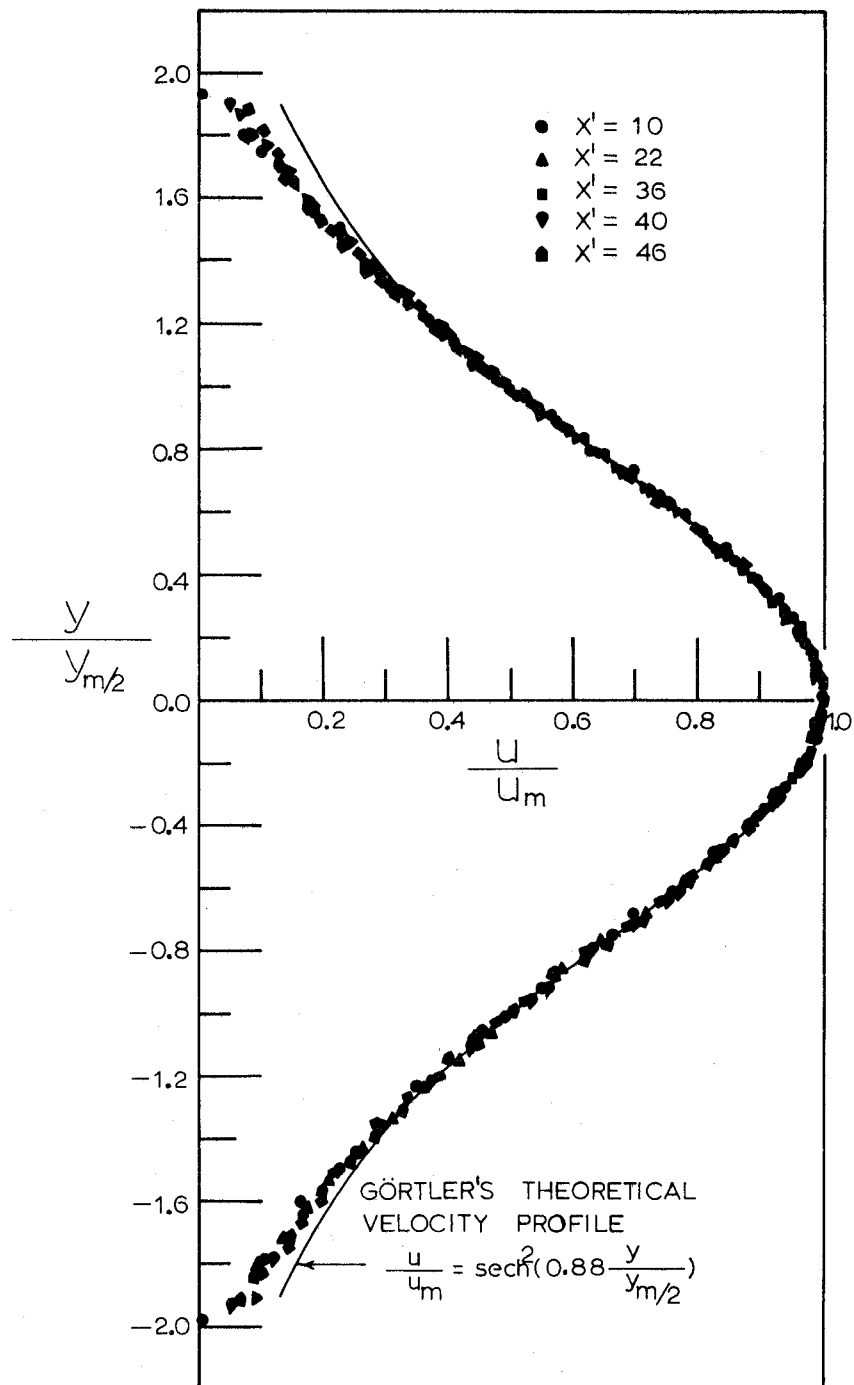
Fig. 6   NON-DIMENSIONAL VELOCITY PROFILES OF THE
FREE JET
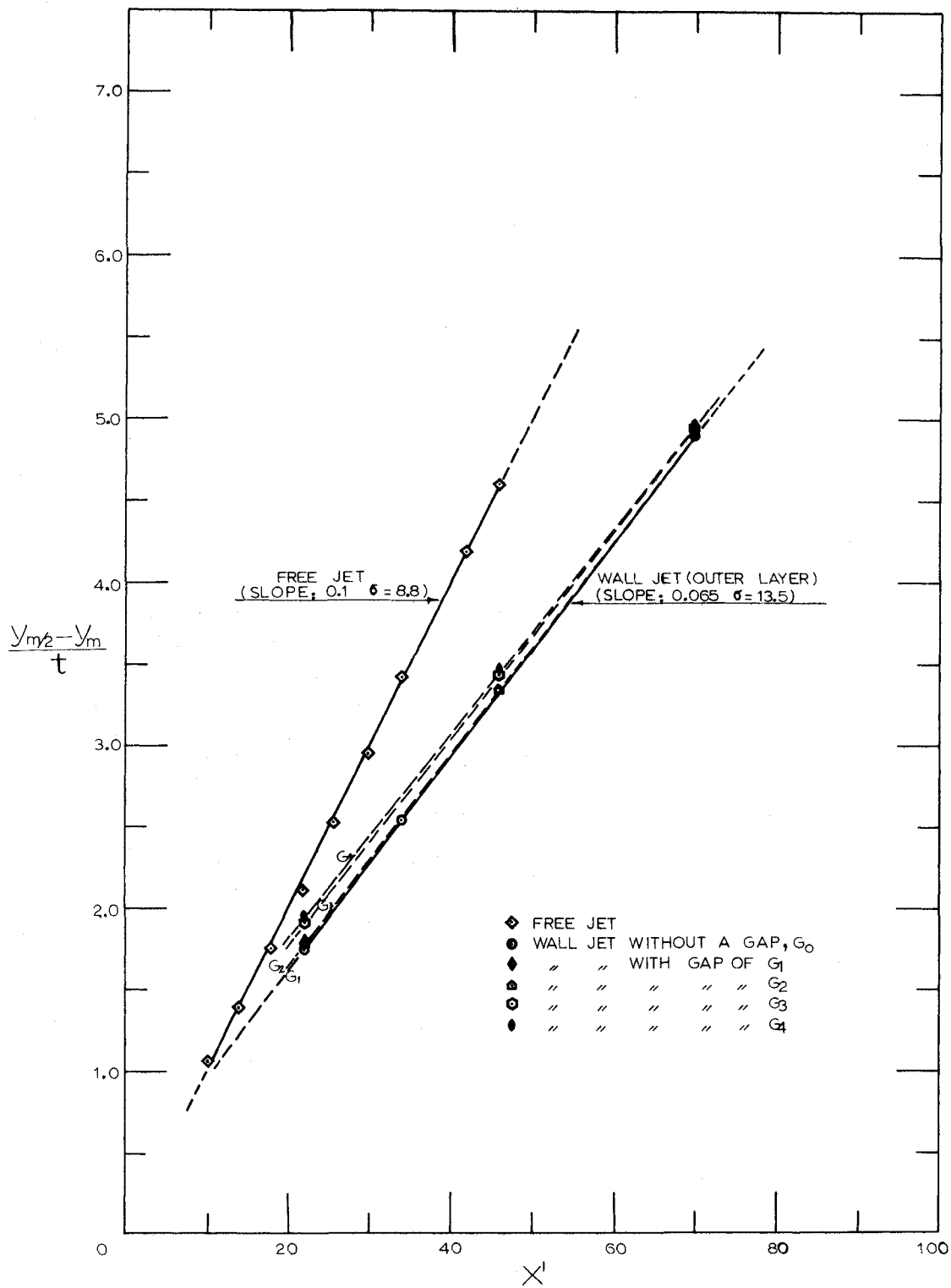
Fig. 7a   GROWTH OF FREE JET AND WALL JET WITHOUT A GAP AND
WITH GAPS OF G_1, G_2, G_3 AND G_4
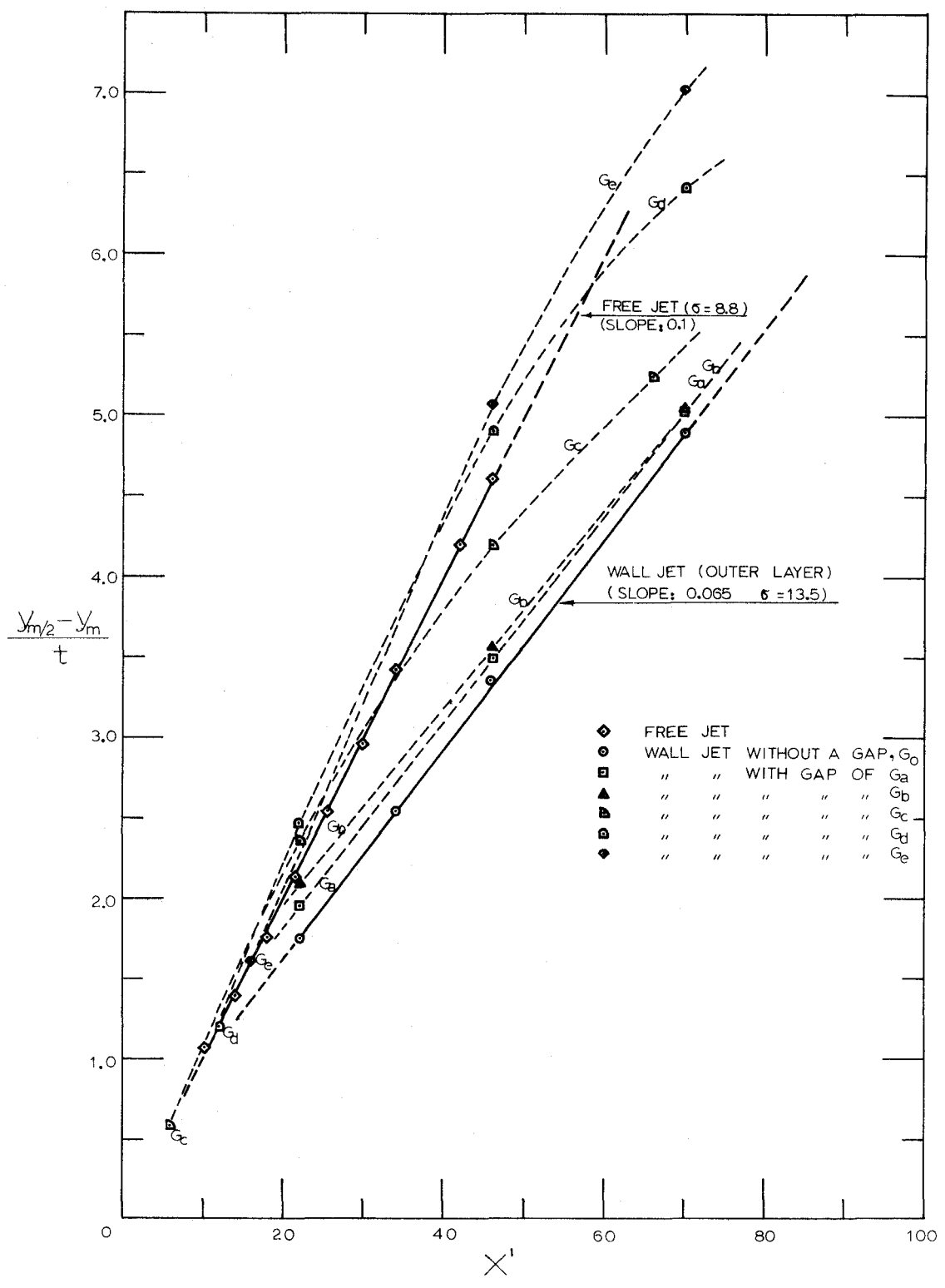
Fig. 7b   GROWTH OF FREE JET AND WALL JET WITHOUT A GAP AND
WITH GAPS OF G_a, G_b, G_c, G_d AND G_e
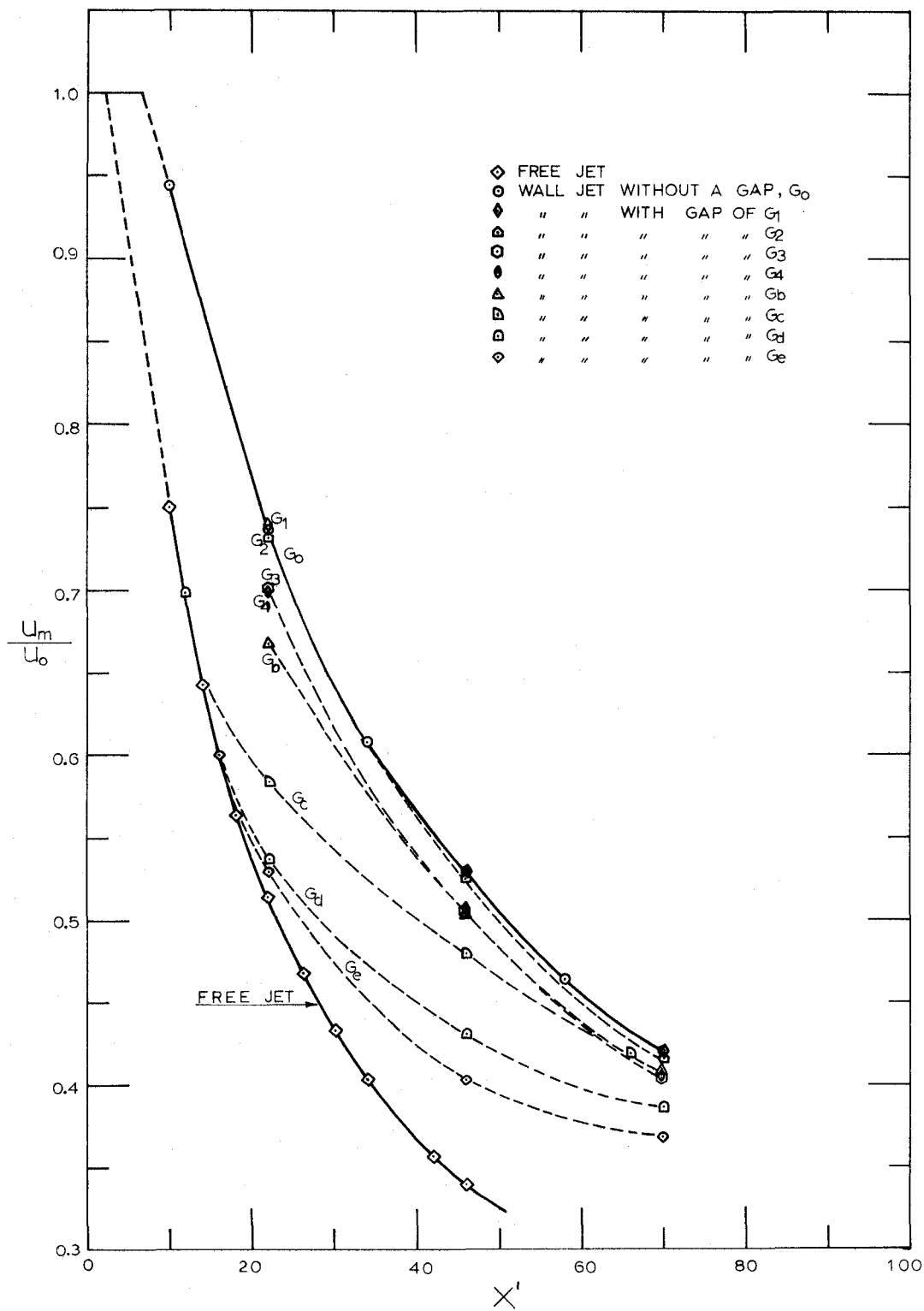
Fig. 8   MAXIMUM   VELOCITY   DECAY   OF   FREE   JET   AND   WALL   JET   WITH   AND
WITHOUT   A   GAP
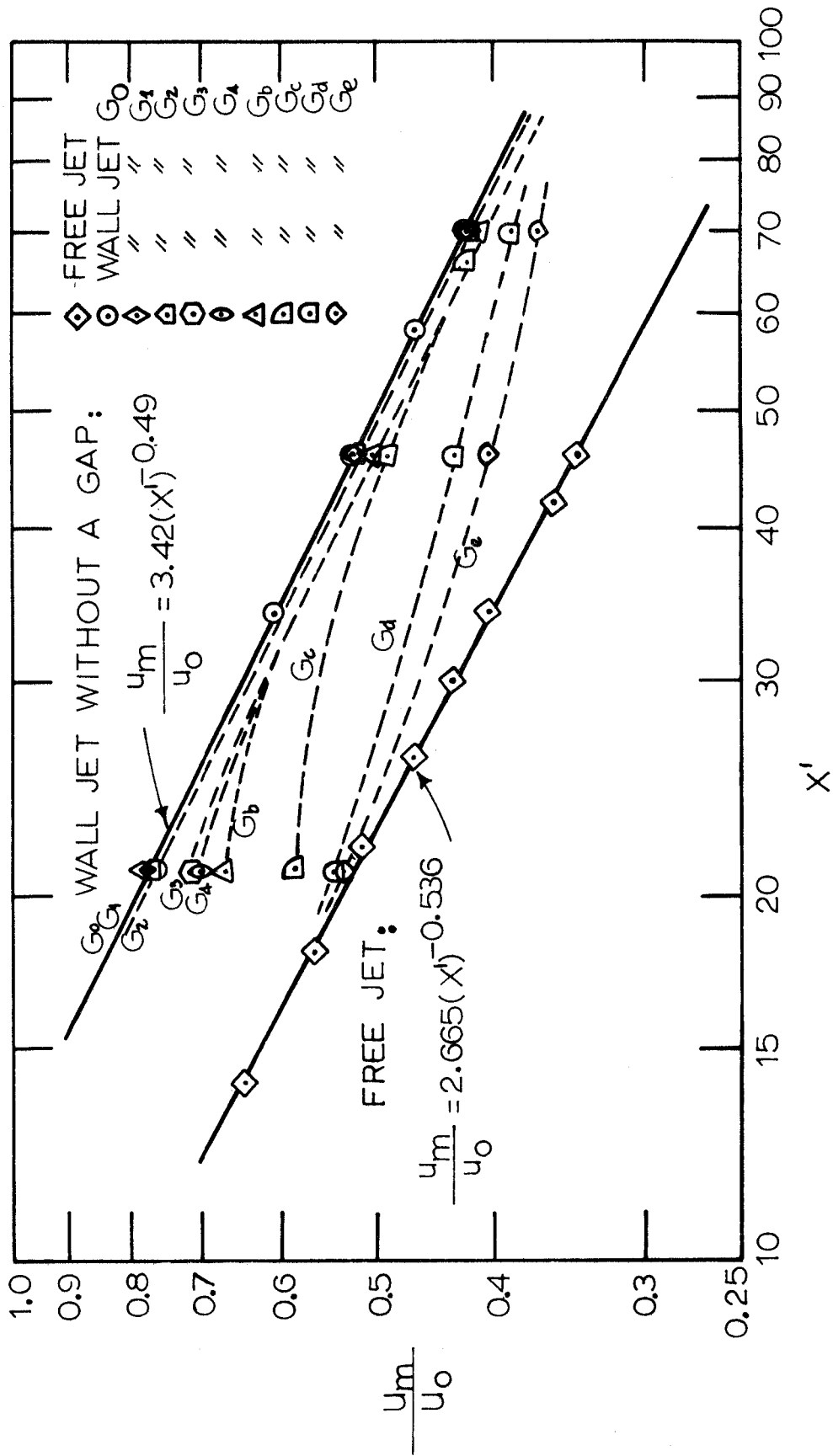
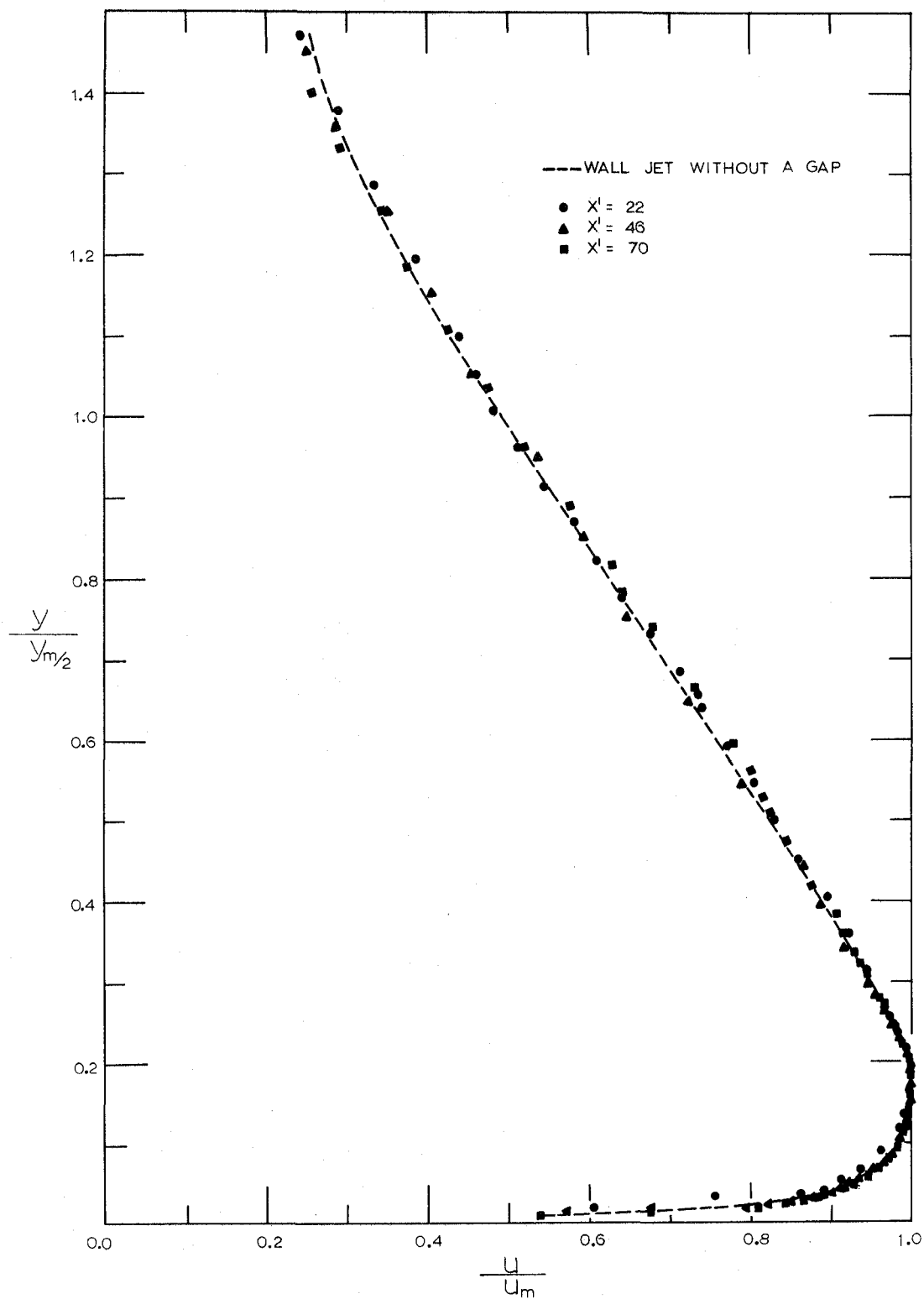Fig. 9   LOGARITHMIC PLOT OF MAXIMUM VELOCITY DECAY OF FREE JET AND WALL JET
WITH AND WITHOUT A GAP
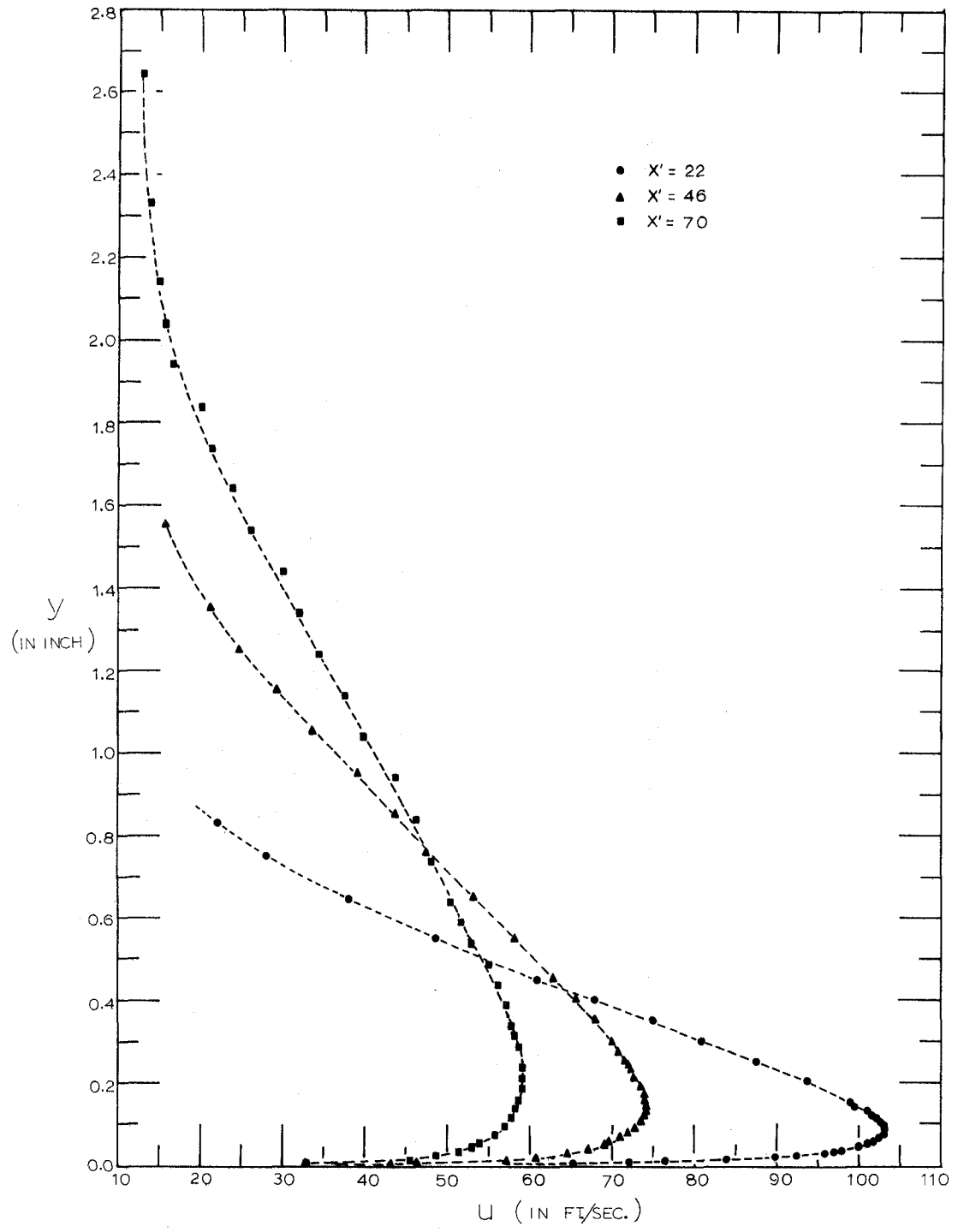
Fig. 10. DIMENSIONAL VELOCITY PROFILE OF A WALL JET WITH ZERO GAP
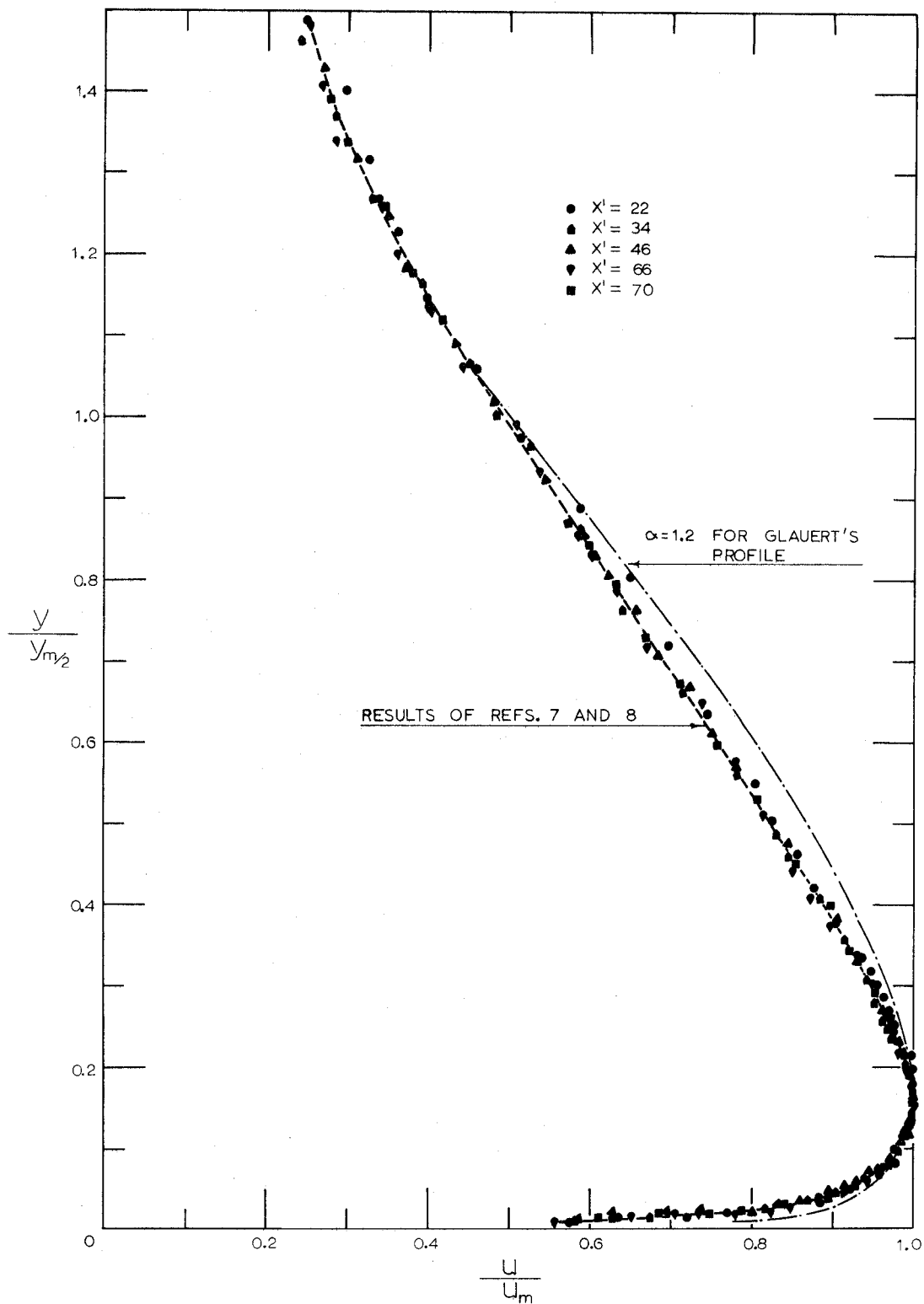
Fig. 11   NON-DIMENSIONAL VELOCITY PROFILE OF WALL JET WITHOUT A GAP
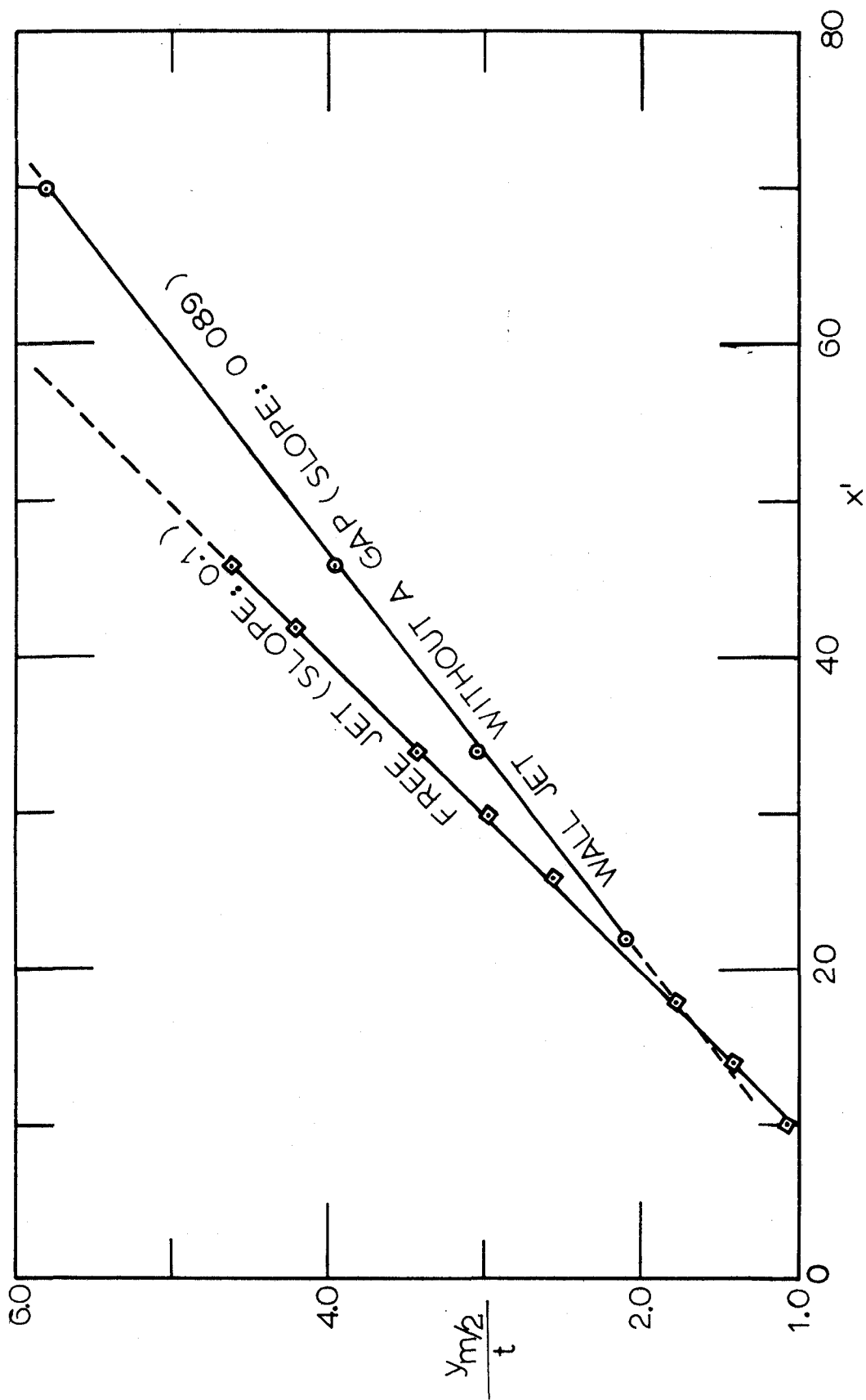
Fig. 12   GROWTH OF FREE JET AND WALL JET WITHOUT A GAP

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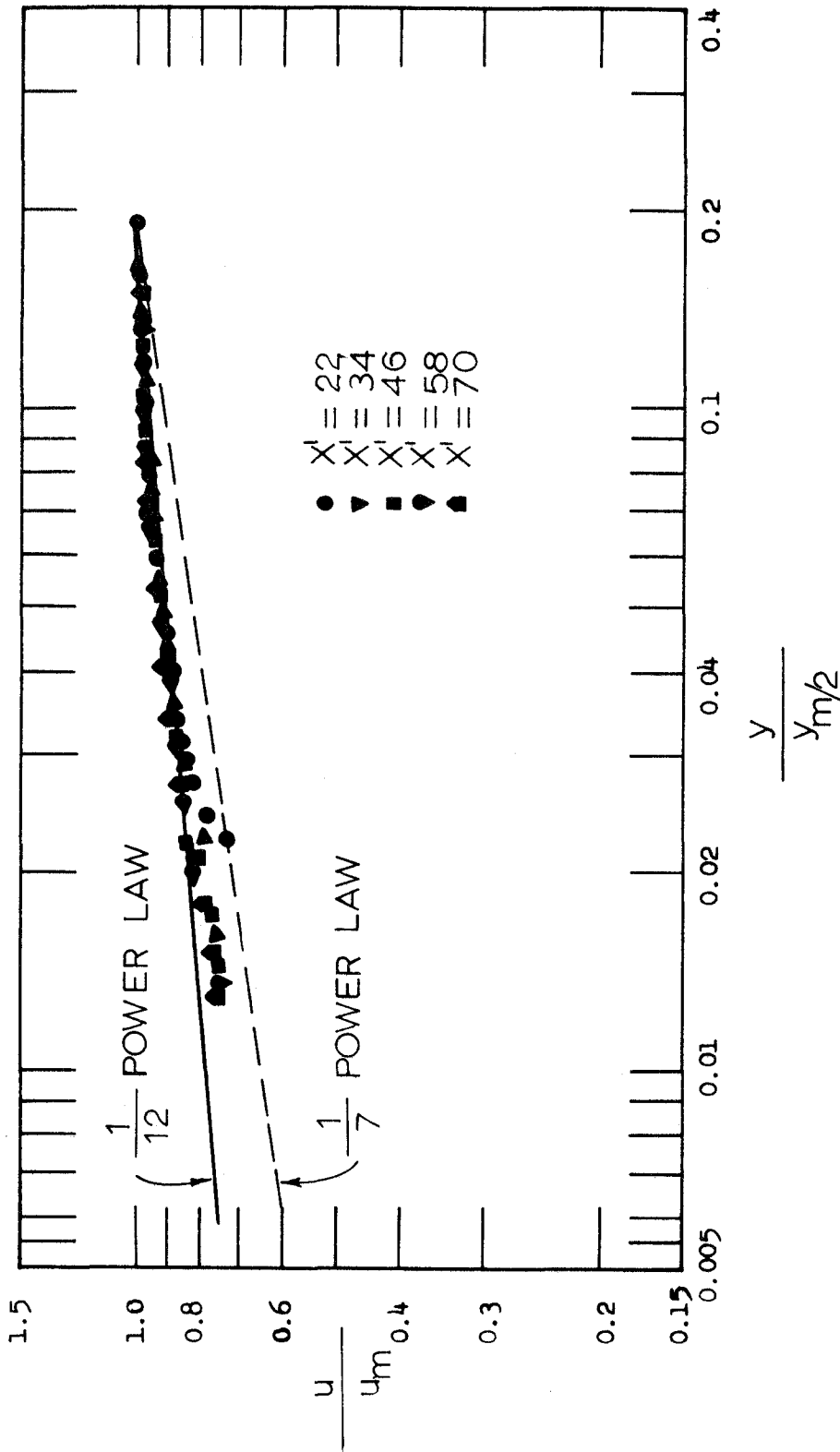
Fig. 13   NON-DIMENSIONAL WALL JET INNER LAYER VELOCITY PROFILE

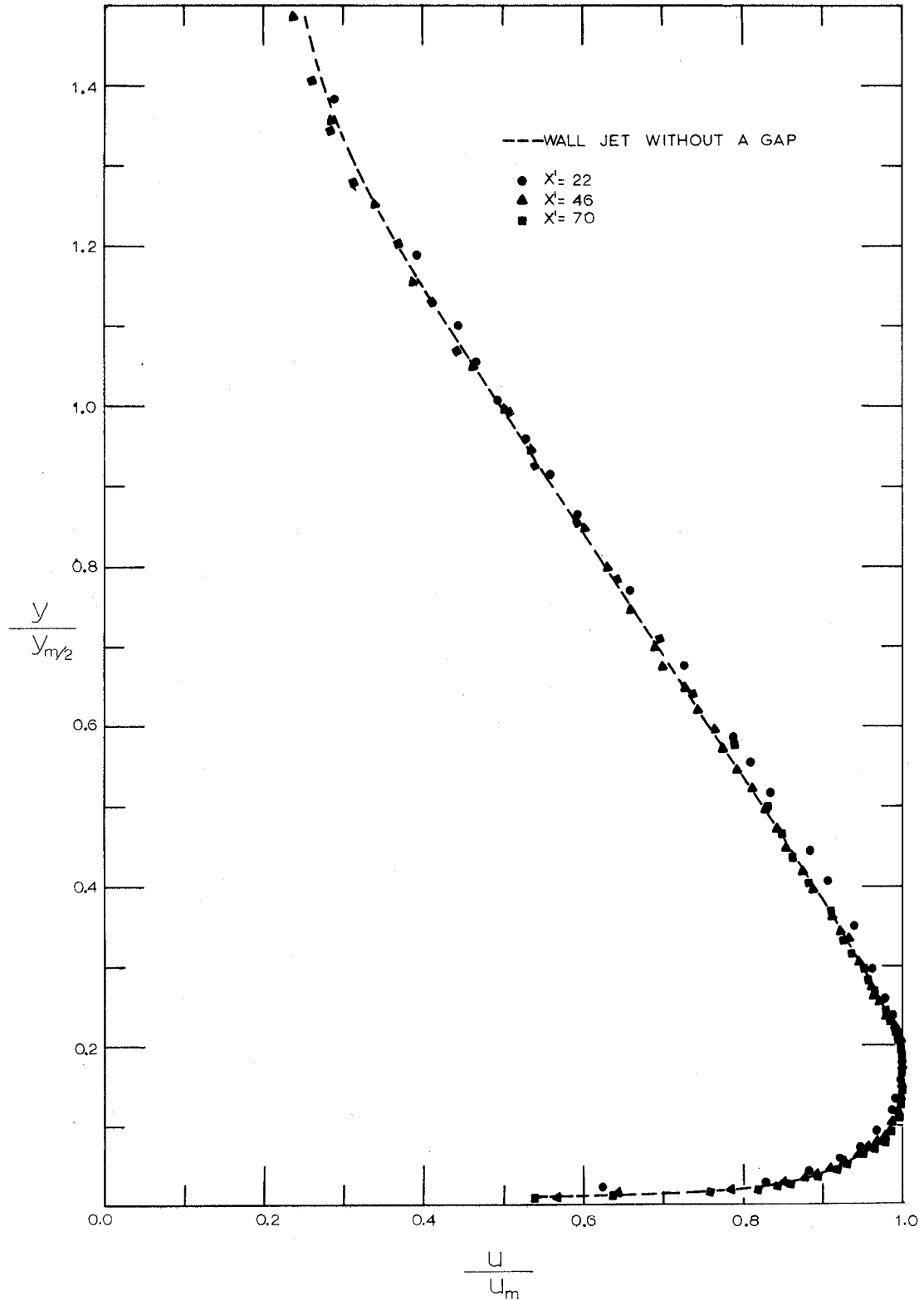Fig. 14a   NON-DIMENSIONAL VELOCITY PROFILES OF WALL JET WITH GAP OF G_1

Fig. 14b   NON-DIMENSIONAL   VELOCITY   PROFILES   OF   WALL   JET   WITH   GAP   OF G_2
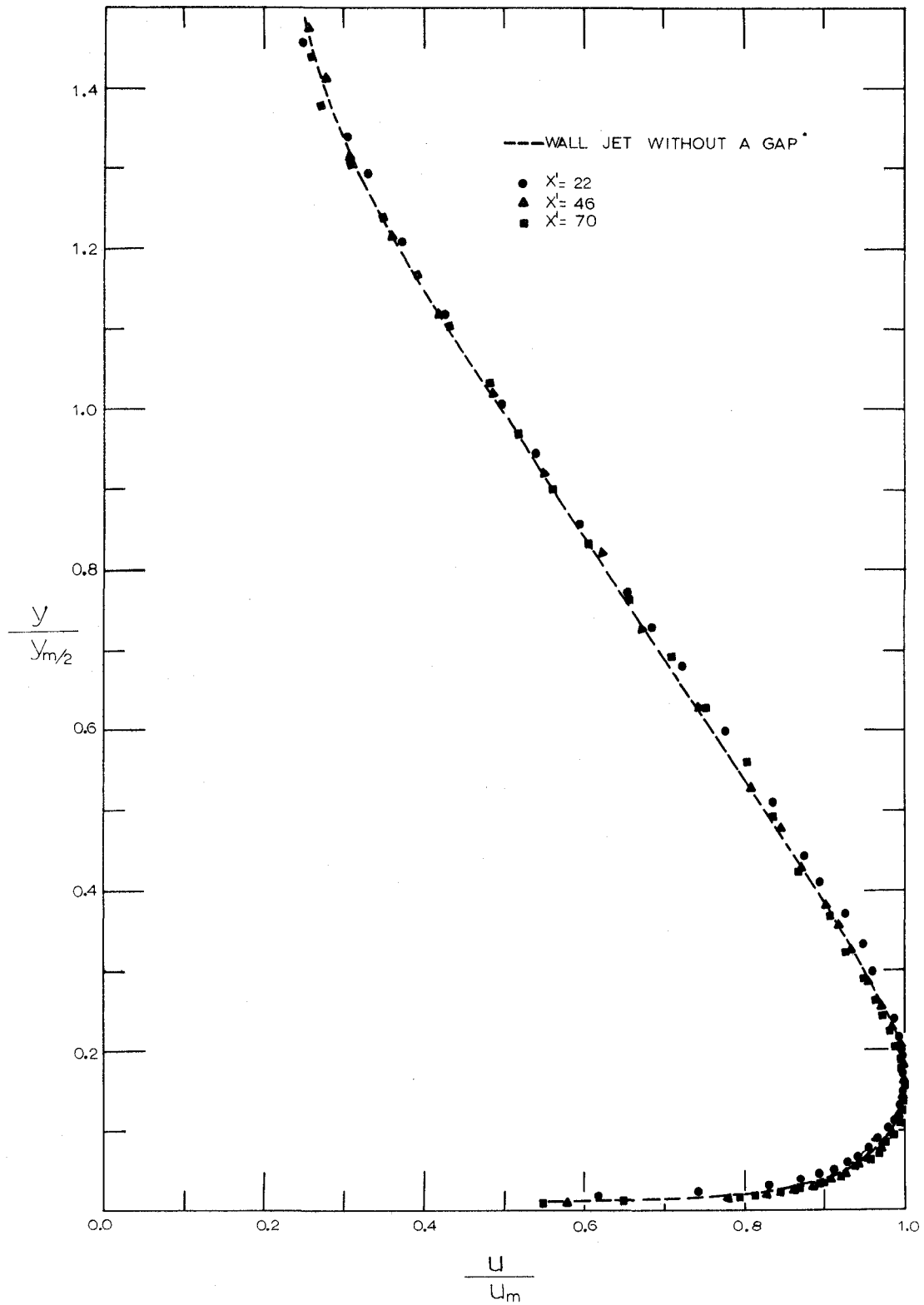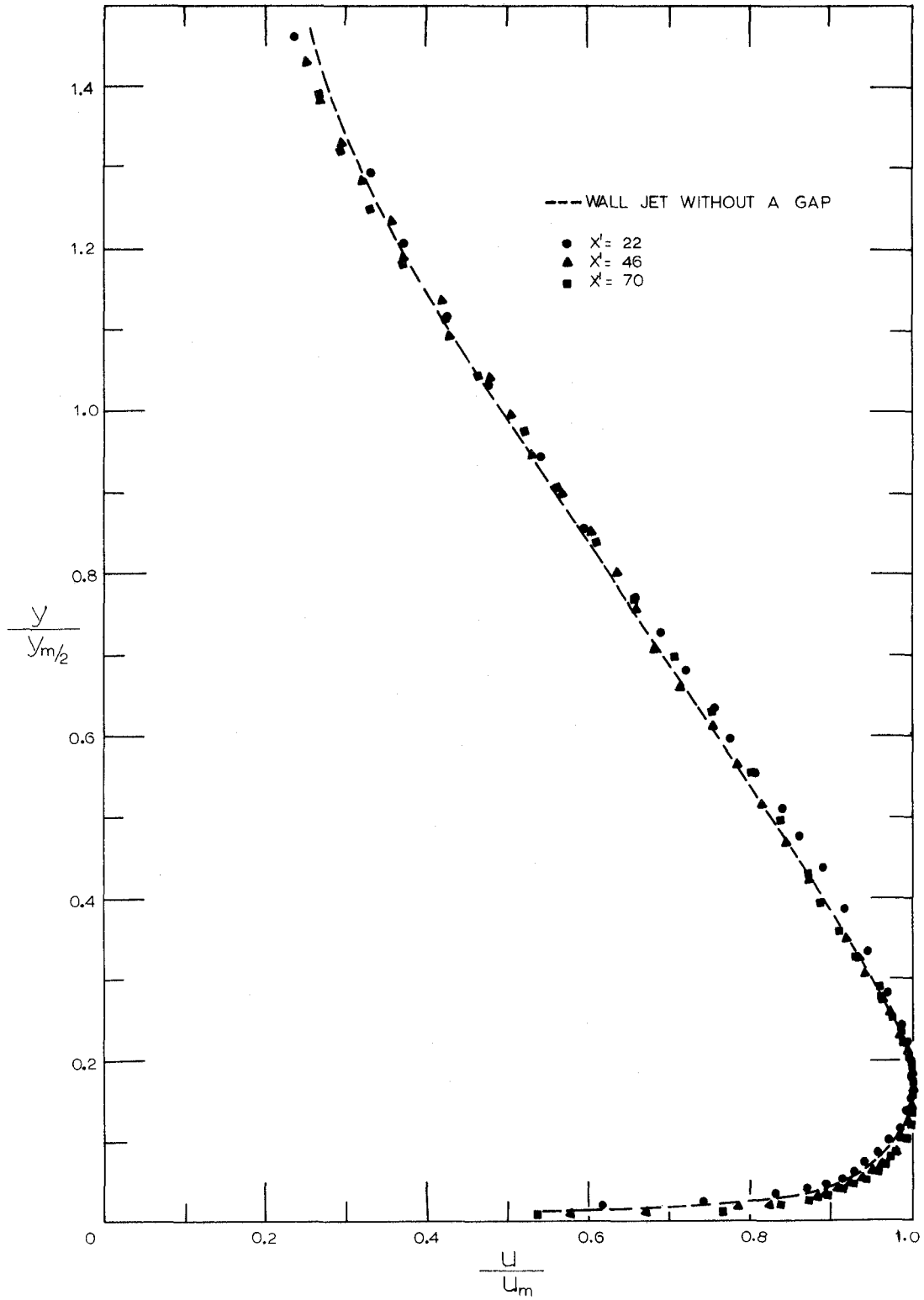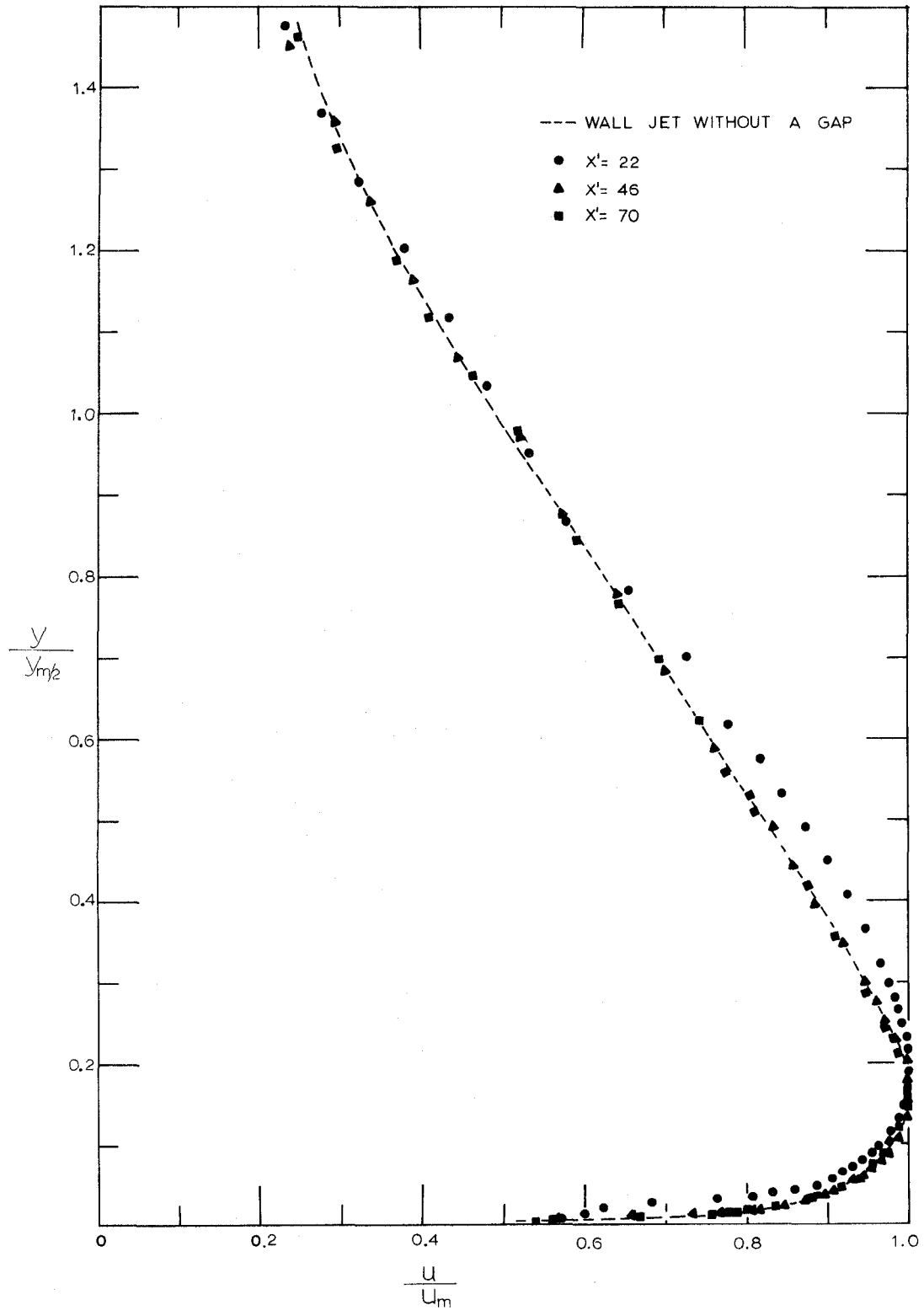
The legend reads:

- - - - WALL JET WITHOUT A GAP
● $X^1 = 22$
▲ $X^1 = 46$
■ $X^1 = 70$

The vertical axis is labeled $\dfrac{y}{y_{m/2}}$ with values 0.2, 0.4, 0.6, 0.8, 1.0, 1.2, 1.4.

The horizontal axis is labeled $\dfrac{U}{U_m}$ with values 0.0, 0.2, 0.4, 0.6, 0.8, 1.0.

Fig. 14c   NON-DIMENSIONAL VELOCITY PROFILES OF WALL JET WITH GAP OF G_3

Fig. 14d   NON-DIMENSIONAL VELOCITY PROFILES OF WALL JET WITH GAP OF G_4
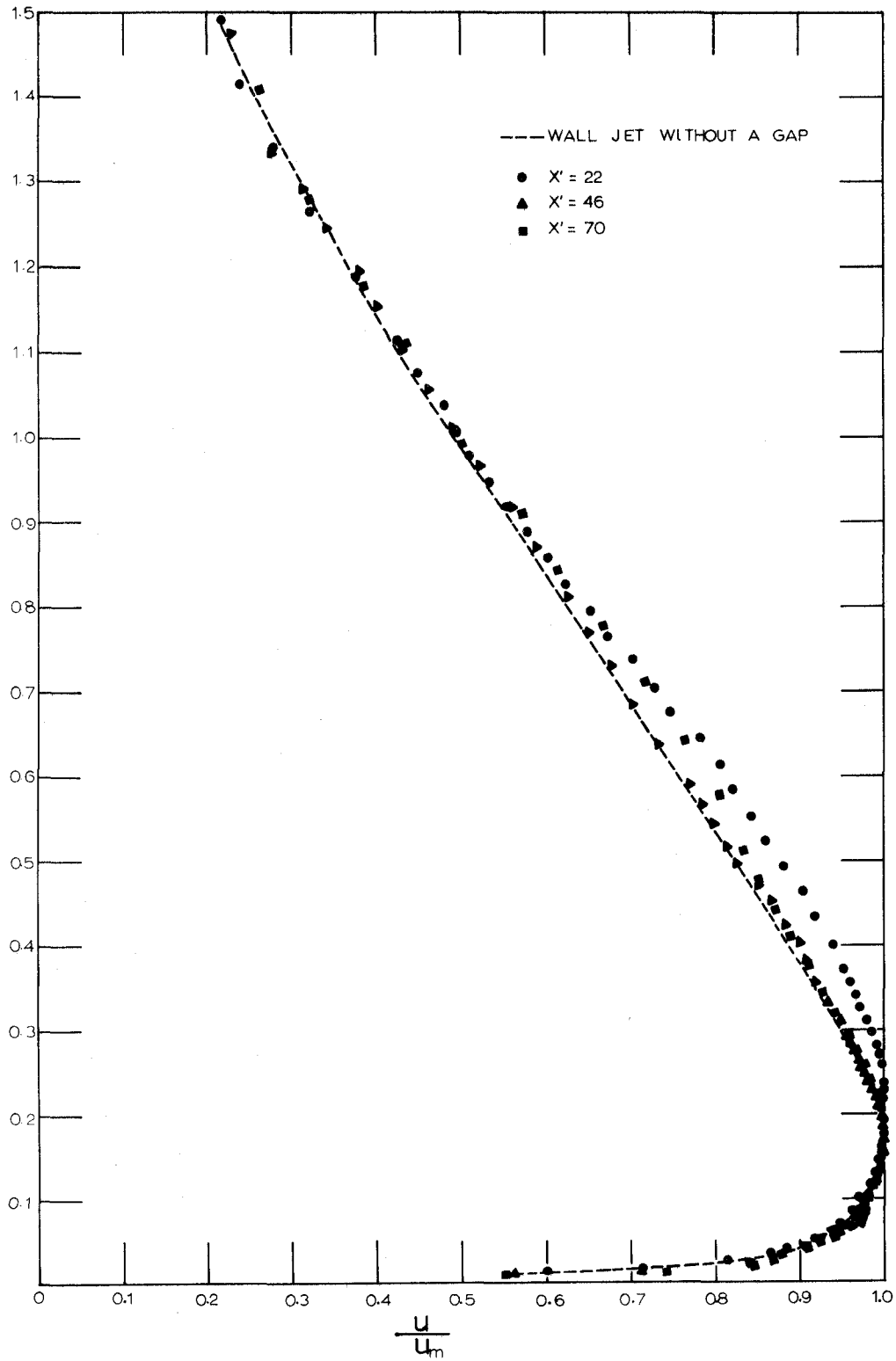
Legend within figure:
- - - WALL JET WITHOUT A GAP
● $X' = 22$
▲ $X' = 46$
■ $X' = 70$

Axes: vertical axis $\dfrac{y}{y_{m/2}}$ (values 0.2, 0.4, 0.6, 0.8, 1.0, 1.2, 1.4); horizontal axis $\dfrac{U}{U_m}$ (values 0, 0.2, 0.4, 0.6, 0.8, 1.0)

Fig. 15a   NON-DIMENSIONAL VELOCITY PROFILES OF WALL JET WITH GAP OF G_a

Fig. 15b   NON-DIMENSIONAL VELOCITY PROFILES OF WALL JET WITH GAP G_b
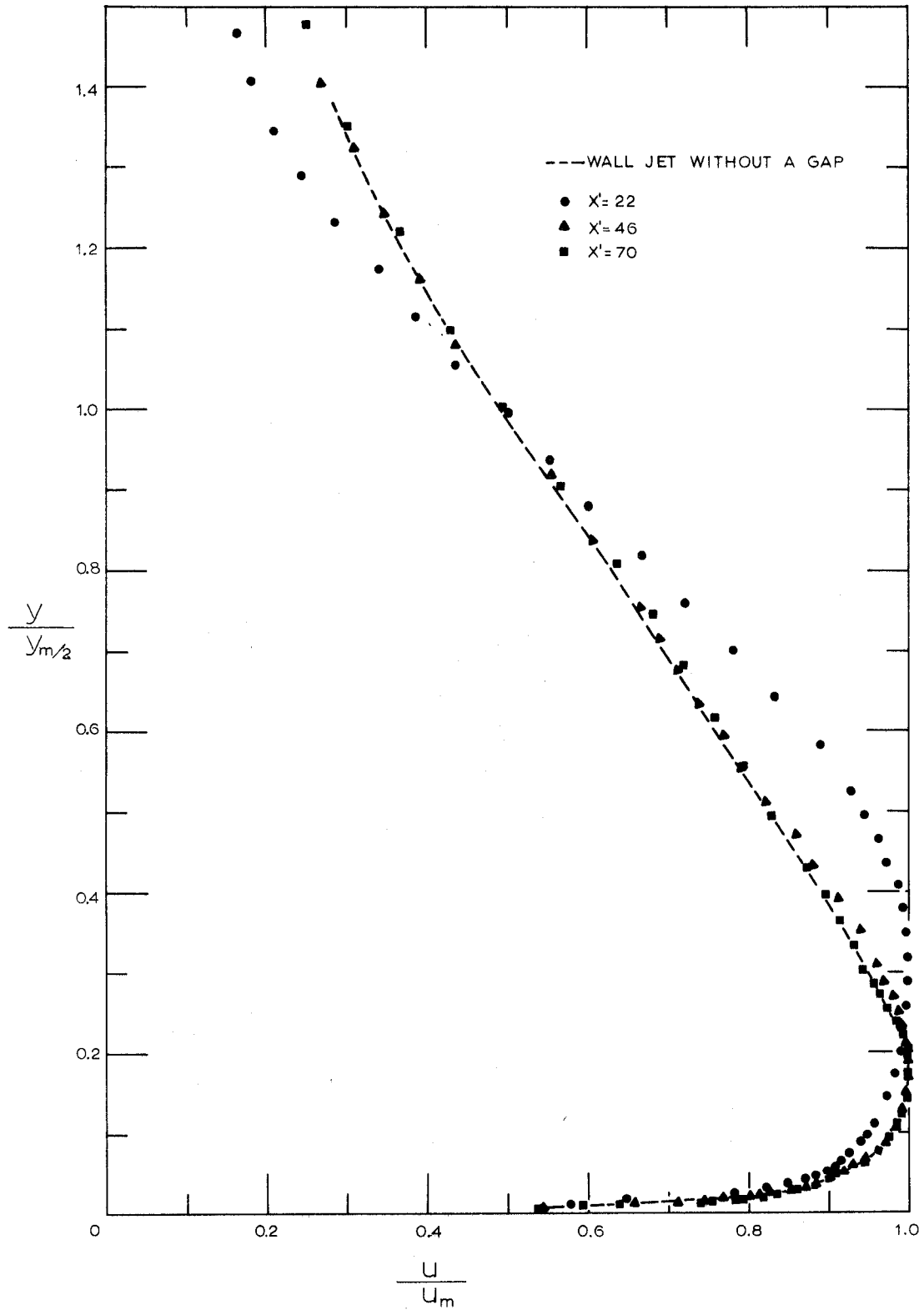
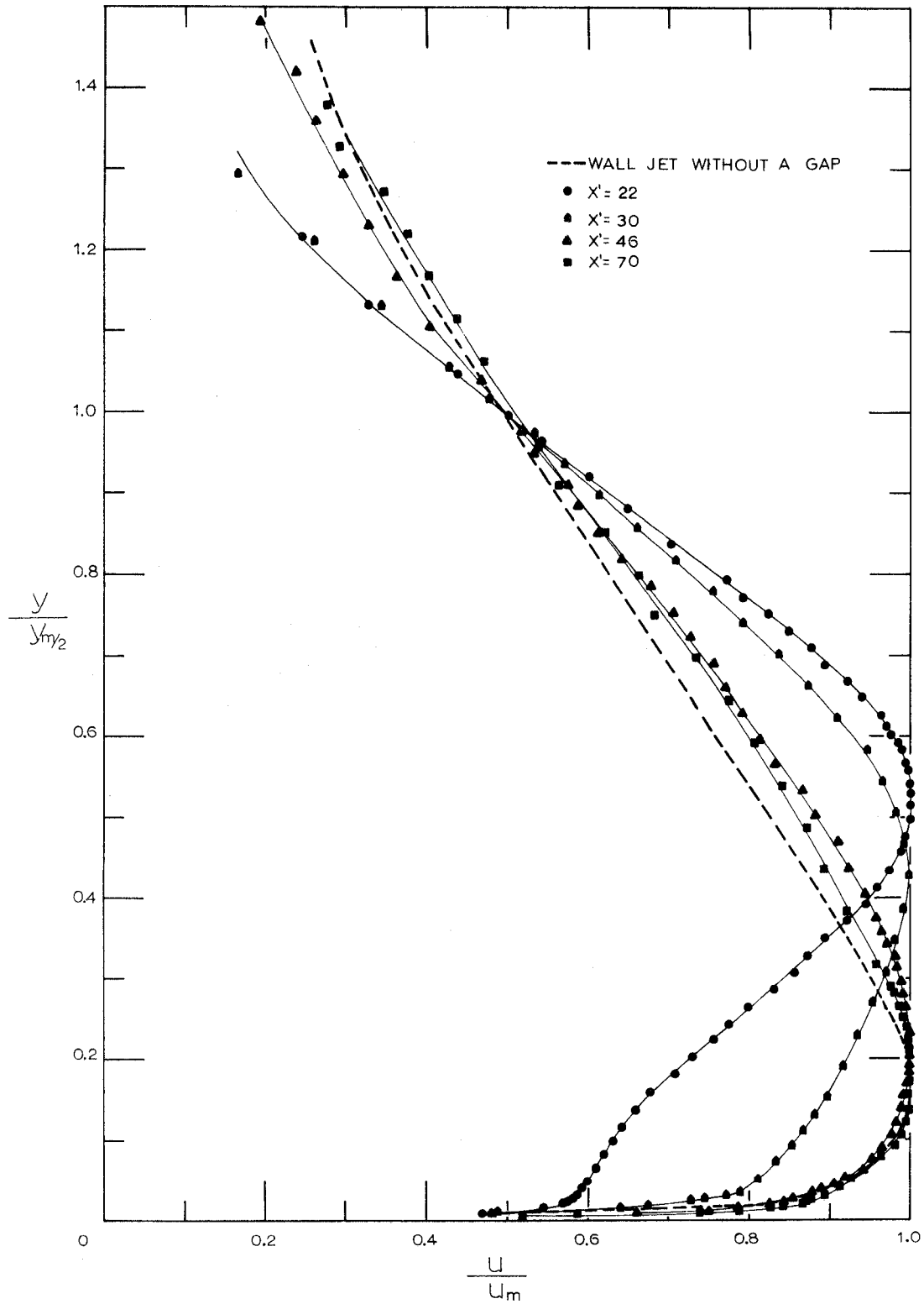Fig. 15c   NON-DIMENSIONAL VELOCITY PROFILES OF WALL JET WITH GAP OF G_c

Fig. 15d   NON-DIMENSIONAL VELOCITY PROFILES OF WALL JET WITH GAP OF G_d
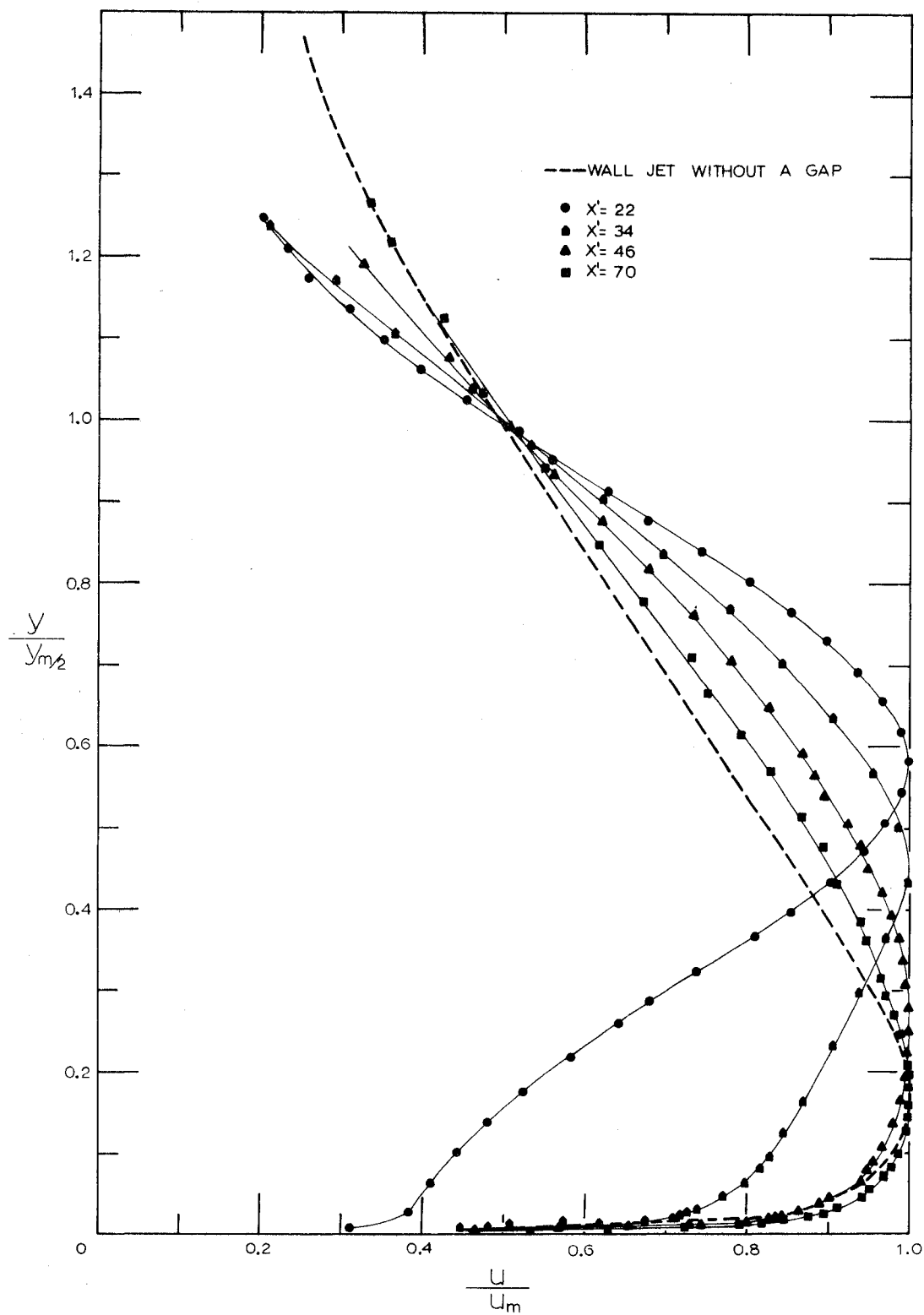
Fig. 15e   NON-DIMENSIONAL VELOCITY PROFILES OF WALL JET WITH GAP OF G_e
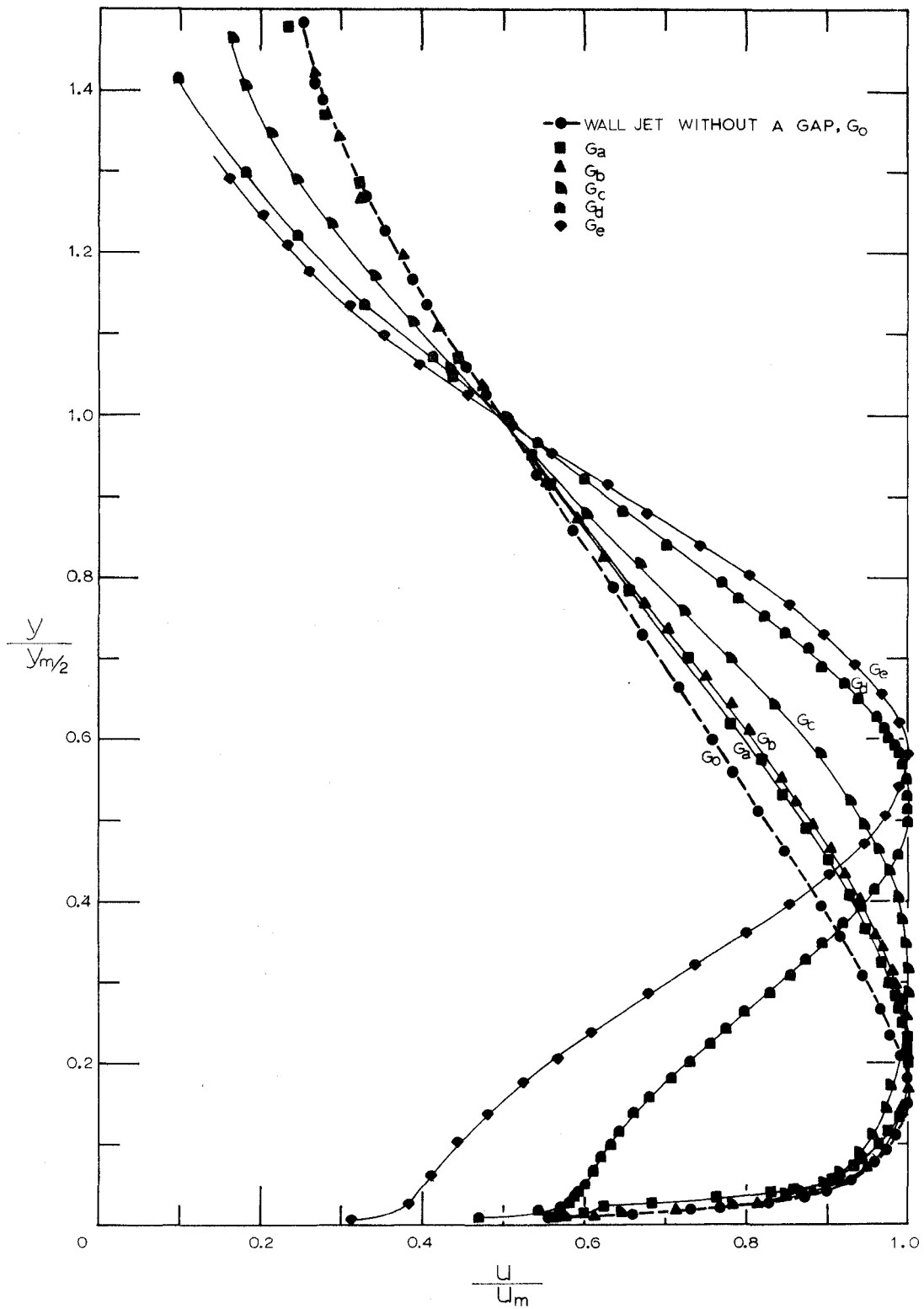
Fig. 16   NON-DIMENSIONAL VELOCITY PROFILES OF WALL JET WITHOUT A GAP
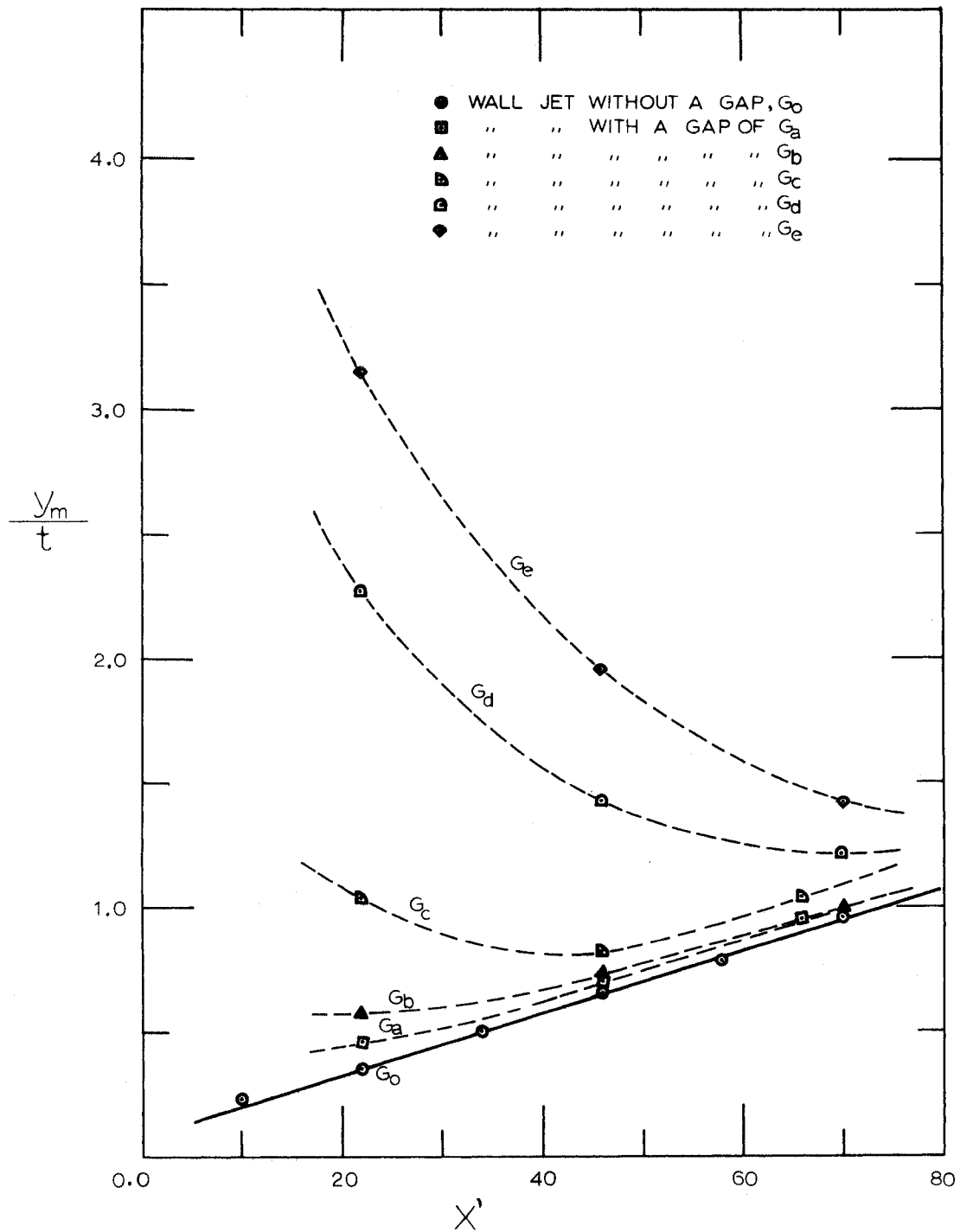AND WITH VARIOUS GAPS AT $X' = 22$

Fig. 17   INNER LAYER GROWTH FOR WALL JET WITH
            AND WITHOUT A GAP

VITA AUCTORIS

1937   Born in Nanking, China, on April 11.

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1965   Currently a candidate for the Degree of Master of Applied

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