TRIUMF	4004 WESBROOK MALL, UBC CAMPUS, VANCOUVER, B.C. V6T 2A3			
DESIGN NOTE	NAME J.J. Burgerjon*	DATE June 1983	FILE NO. TRI-DN-83-27	PAGE 1 of 19

SUBJECT: Transportation of radio-isotopes via a long "air-chute"**

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**Also known as a "Pneumatic transfer system"
"Rabbit system"

This note presents the text and illustrations for a poster paper to be presented at the CAP Meeting in Victoria on June 27, 1983. The display will also include colour photographs of the CP-42 cyclotron and the PET (not included in this design note) and some actual "rabbits" and pieces of rabbit tubing.

References:

J.J. Burgerjon, J. Lenz, B.T. Trevitt: "Long distance rabbit tests". TRI-DN-79-8, June 1979.

J.A. Correia, W.H. Buceliwicz, H.W. Strauss, N.M. Alpert, G.L. Brownell, and J.M. Taveras, "Transportation of short-lived positron emitter from a medical cyclotron to a remote imaging suite", Med. Phys. 10(2), Mar/Apr 1983.

Design Criteria

The Positron Emission Tomograph (PET) at the UBC Hospital requires ^{18}F, ^{11}C, ^{14}N and ^{15}O having half lives of 110, 20, 10 and 2 minutes respectively.

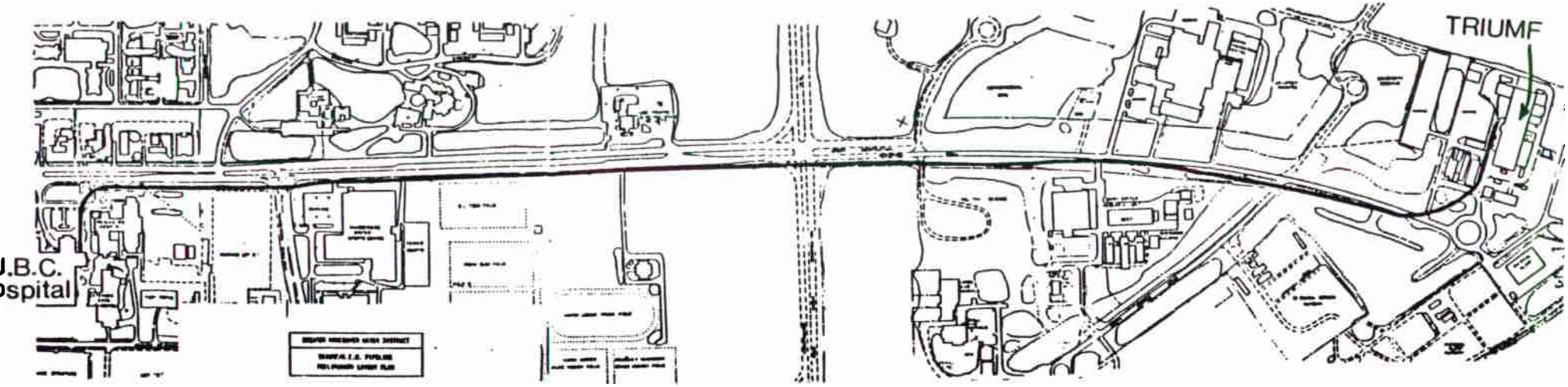
The 42 MeV Cyclotron that produces these isotopes is located at TRIUMF. The PET is located at the UBC Hospital.

The distance between TRIUMF and the hospital is 2.4 km (Fig. 1). To minimize decay, the time to transport the isotopes should not be longer than the processing time: approximately 3 minutes.

A fast "rabbit" tube appeared to be the only practical solution to meet this criterion. As far as we could determine, no fast rabbit line of this length had ever been built (Fig. 2).

A full scale prototype test, done in 1979, showed that the above criterion could be met.

Stringent safety criteria also had to be met. This is why, although the transported isotopes are quite harmless because of their short half lives, the line was run 1.20 m underground and is totally encased in concrete of 10 cm minimum thickness. The nine manholes, needed for access, have 60 cm thick concrete covers (Fig. 3). The maximum radiation level at the surface will not exceed 8 microrem per hour.



U. B. C. HOSPITAL / TRIUMF PIPELINE

Fig. 1

SCALE APPROX. 1:8300

FULL SCALE
CROSS SECTION OF DUCT

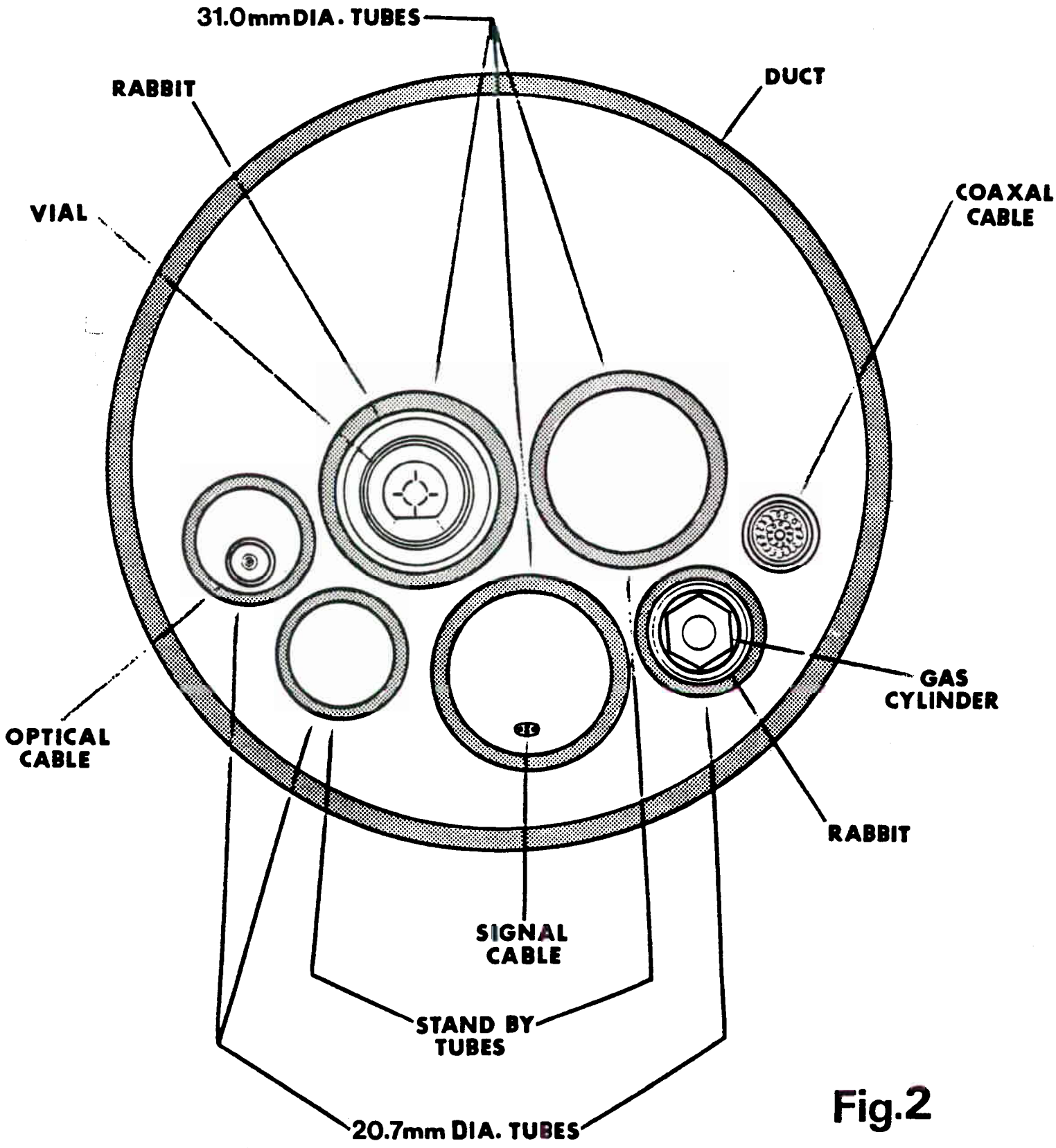
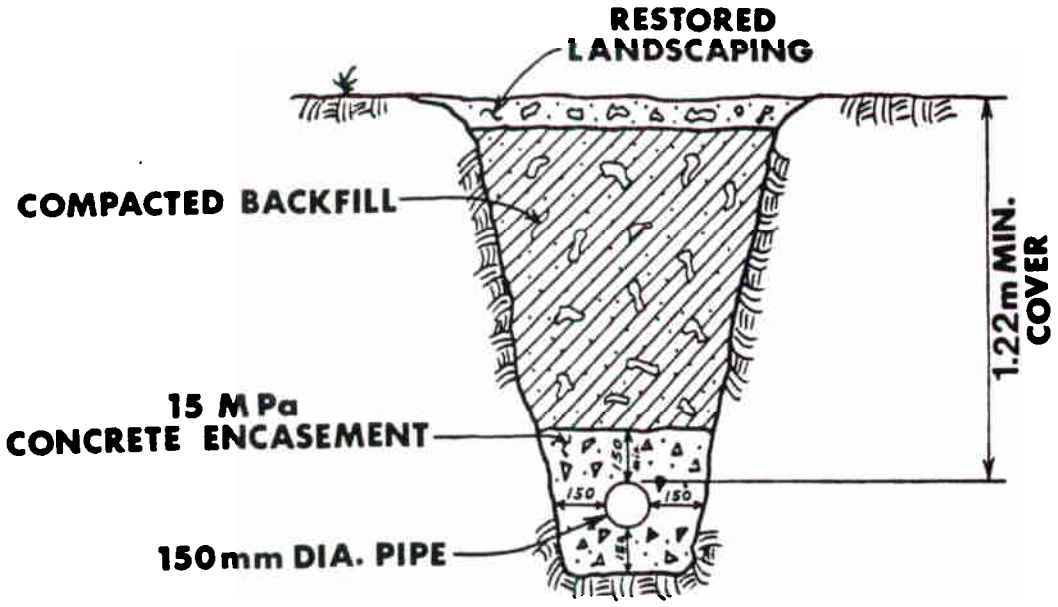
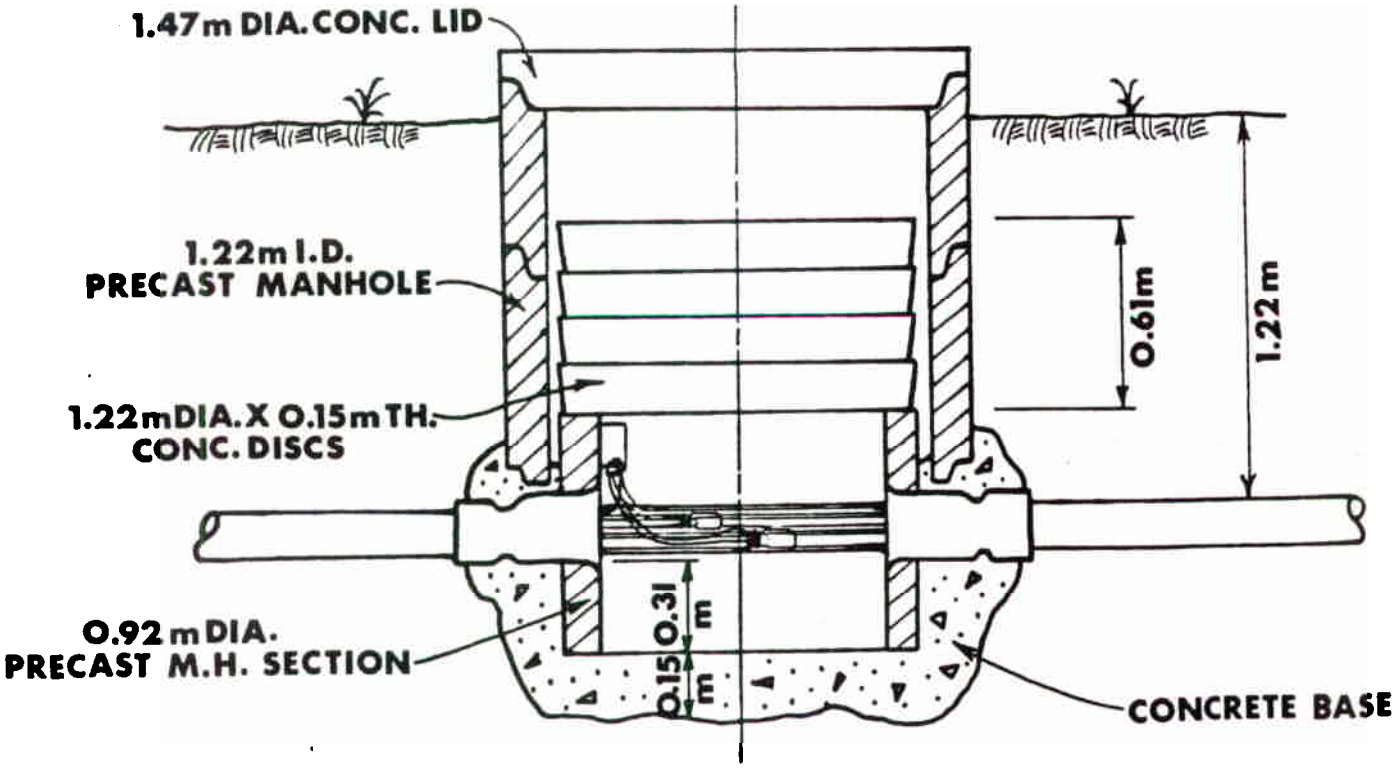


Fig.2



SCALE 1:24

PIPELINE



SCALE 1:24

MANHOLE

Fig.3

How It Works

Like an overgrown pea-shooter!

The capsule or "rabbit", containing the radio-isotope vial, is driven through the tube by air at a pressure of 700 kPa.

Initial acceleration is at ~600 g. During the first few meters the rabbit approaches a speed of several hundred meters per second.

Soon the air being compressed ahead of the rabbit slows it down to something less than the speed of the pressure front.

Towards the end of the tube the flow resistance of the remaining tube decreases and the rabbit picks up speed again (Fig. 4, 5 and 6). The larger diameter rabbits travel faster. In the 1979 test the transit times were limited by the air supply.

It takes only a few kPa to propel the rabbit. The airflow in the tube is hardly affected by the rabbit (Fig. 7, pressure in manhole #9 vs. time).

Transit times were measured as follows:

1979 Test Results: A radio-active source in the rabbit produced a signal in a radiation detector each time the rabbit completed one of the 29 coils of the 2.4 km long tube.

1983 "As Built" Results: A magnet in the rabbit produced a signal in a detector coil each time the rabbit passed the send station, the nine manholes and the receive station (Fig. 8).

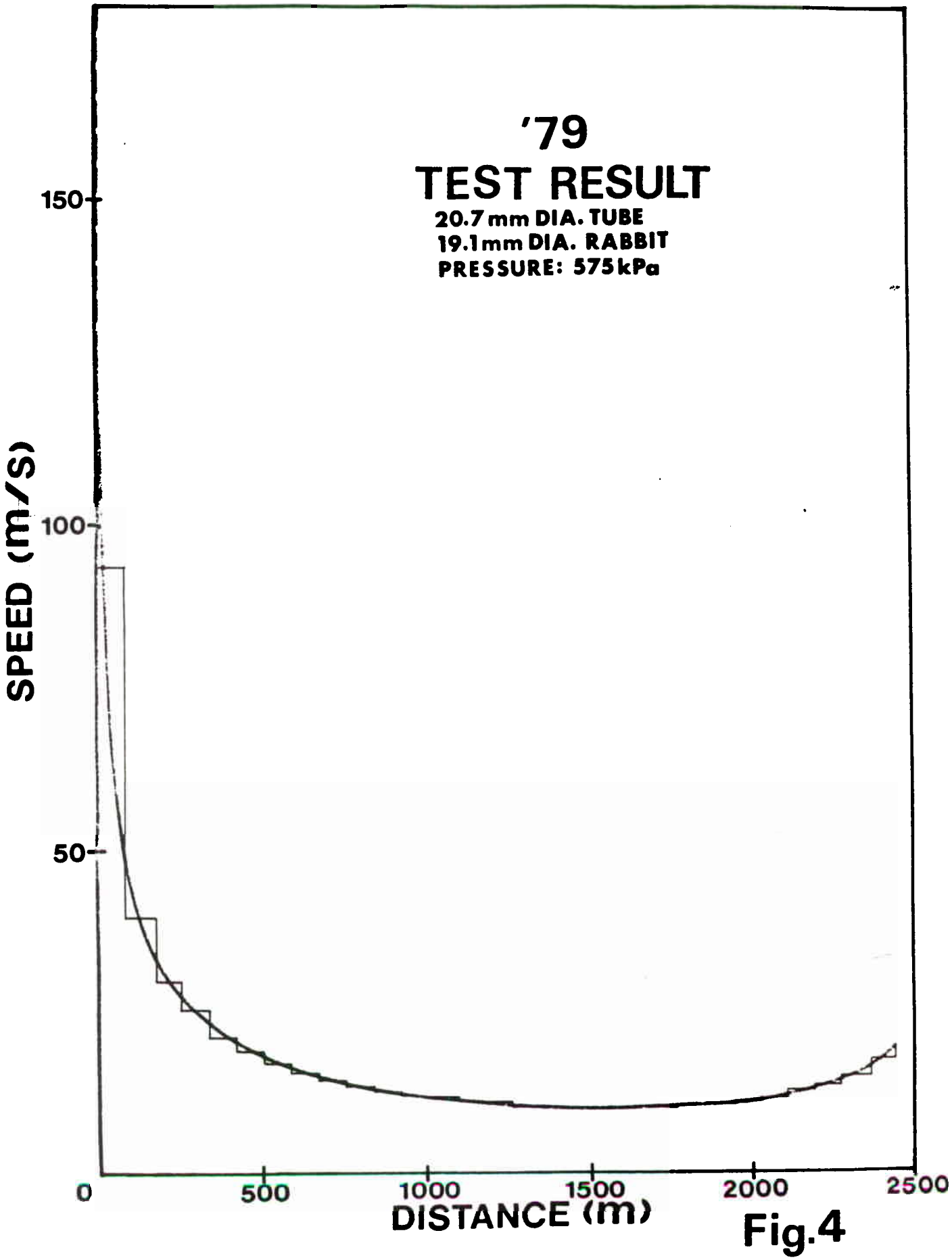

'79
TEST RESULT
20.7 mm DIA. TUBE
19.1 mm DIA. RABBIT
PRESSURE: 575 kPa
150
100
50
0
SPEED (M/S)
500
1000
1500
2000
2500
DISTANCE (m)

Fig.4

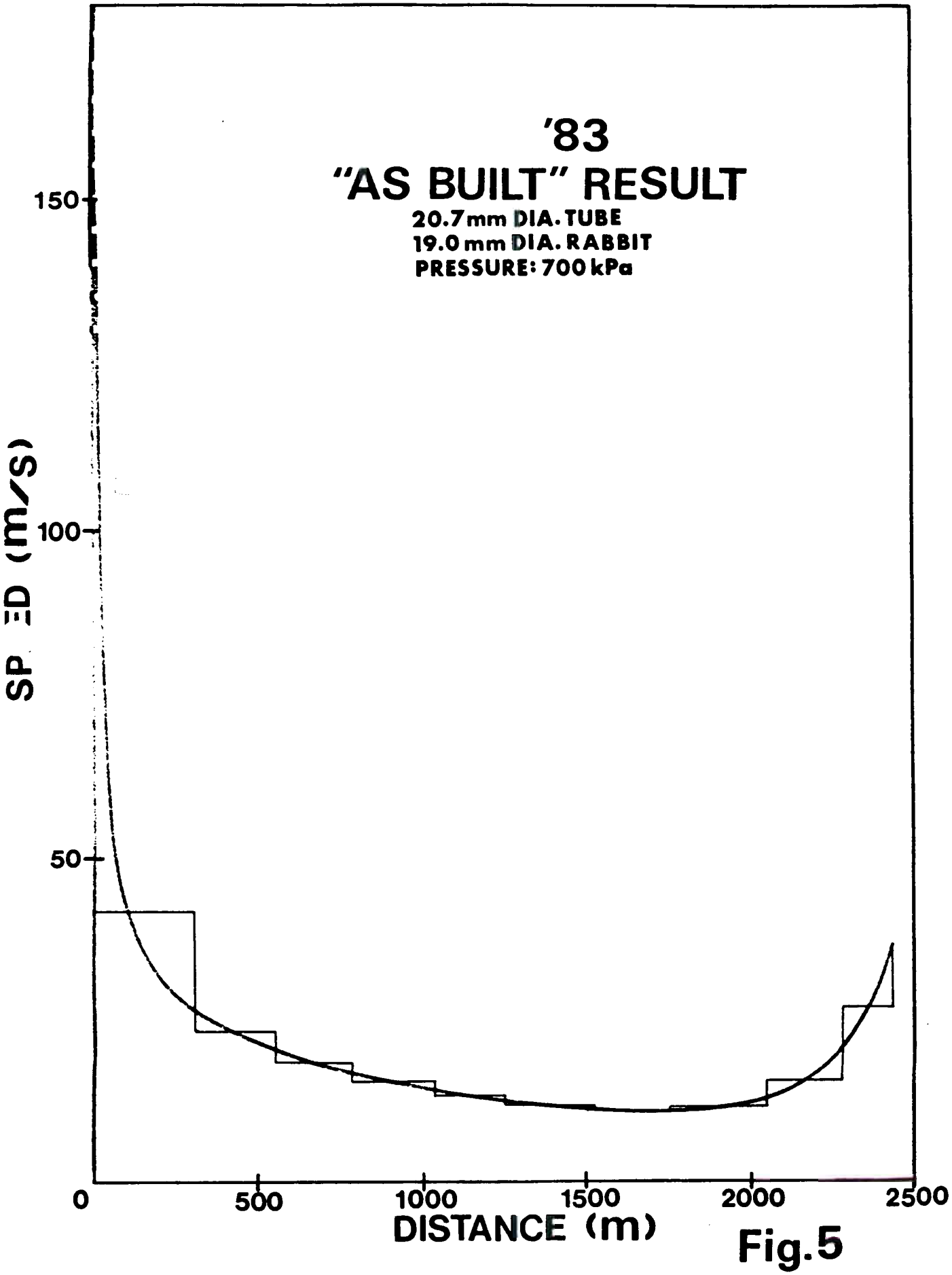

'83
"AS BUILT" RESULT
20.7mm DIA. TUBE
19.0mm DIA. RABBIT
PRESSURE: 700kPa
SPEED (m/s)
150
100
50
0
500
1000
1500
2000
2500
DISTANCE (m)

Fig.5

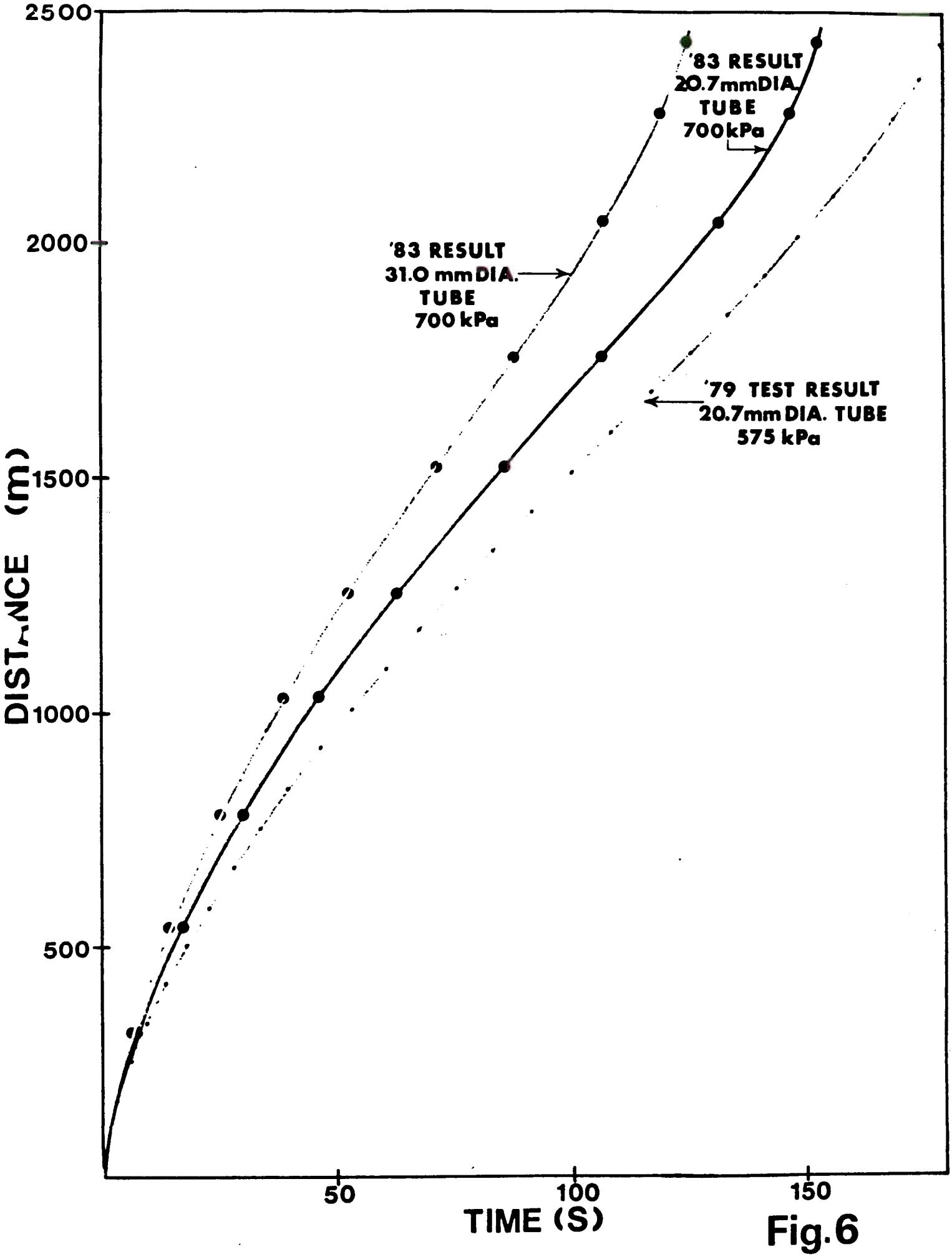

2500
2000
1500
1000
500
DISTANCE (m)
'83 RESULT
20.7mmDIA.
TUBE
700kPa
'83 RESULT
31.0 mmDIA.
TUBE
700 kPa
'79 TEST RESULT
20.7mmDIA. TUBE
575 kPa
50
100
150
TIME (S)

Fig.6

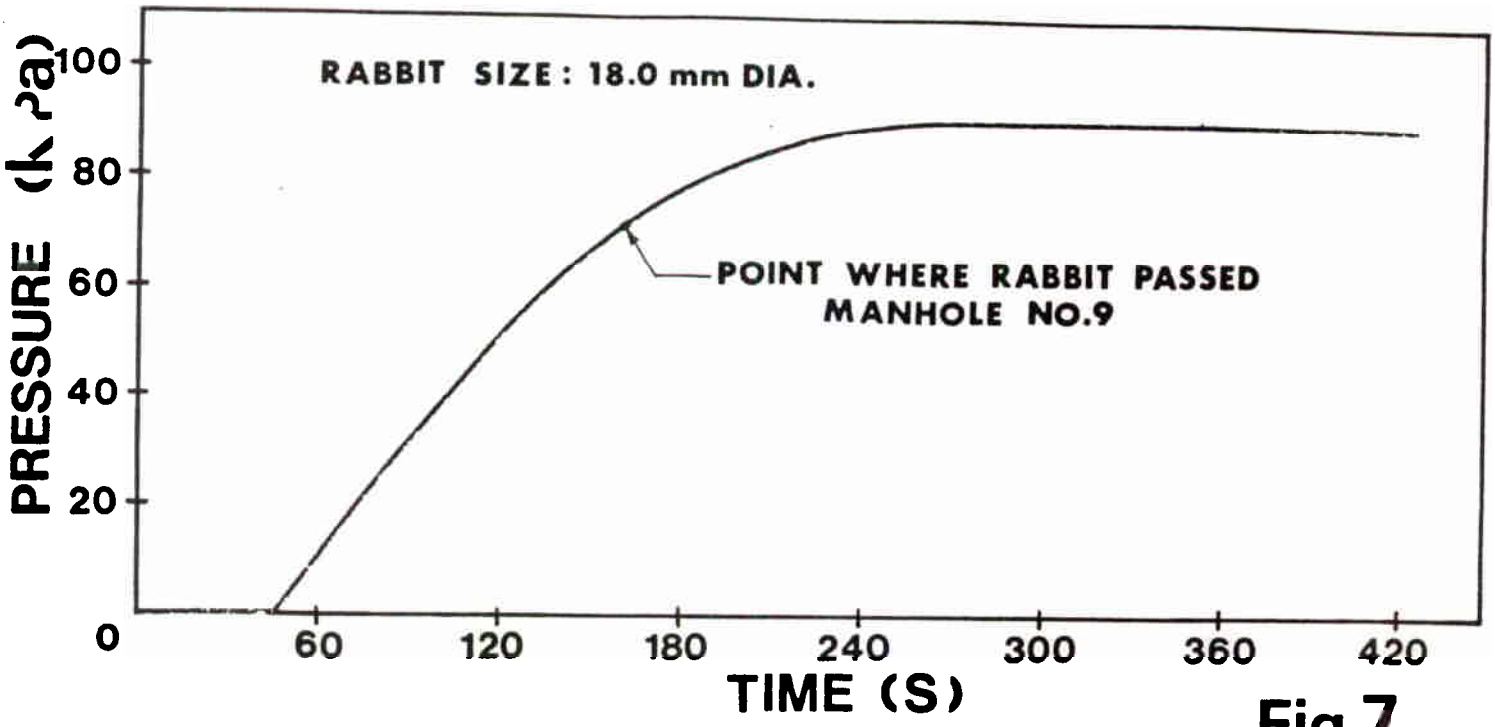

RABBIT SIZE : 18.0 mm DIA.
POINT WHERE RABBIT PASSED MANHOLE NO.9
PRESSURE (kPa)
100
80
60
40
20
0
60
120
180
240
300
360
420
TIME (S)

Fig.7

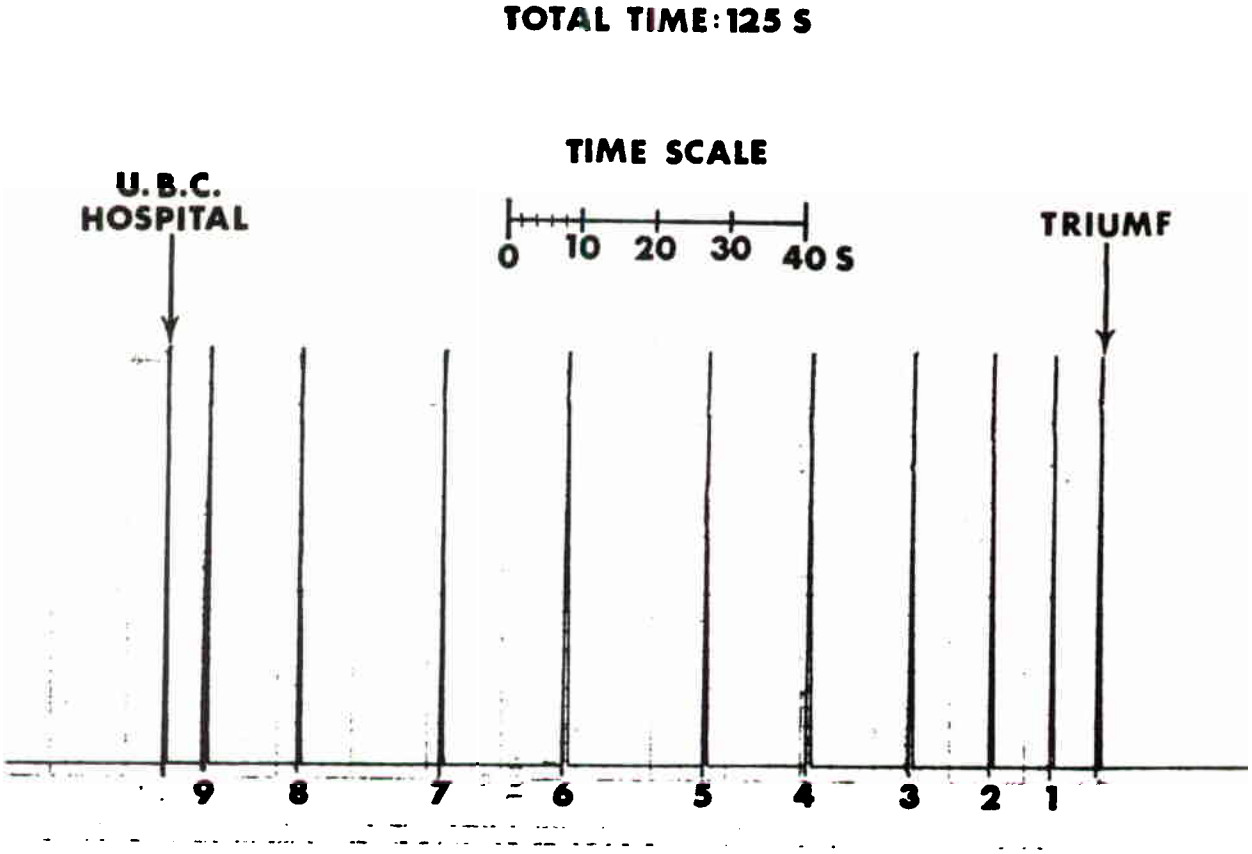

TOTAL TIME: 125 S
TIME SCALE
0 10 20 30 40 S
U.B.C. HOSPITAL
TRIUMF
9 8 7 6 5 4 3 2 1

Fig.8

Variation Of Rabbit Diameter

The rabbit diameter is the most critical parameter. Too close a fit in the tube increases friction. Too loose a fit allows too much air to leak past the rabbit (Fig. 9).

Optimum rabbit/tube dimensions:

Tube inside diameter (mm)	20.7	31.0
Tube nominal tolerance (mm)	±0.10	±0.15
Optimum rabbit diameter (mm)	18.75	28.75
Optimum nominal clearance (mm)	1.95	2.25
Optimum actual clearance (mm)	1.85	2.10

Transit time	31.0 mm dia tube	124 ± 3 s
Transit time	20.7 mm dia tube	153 ± 3 s

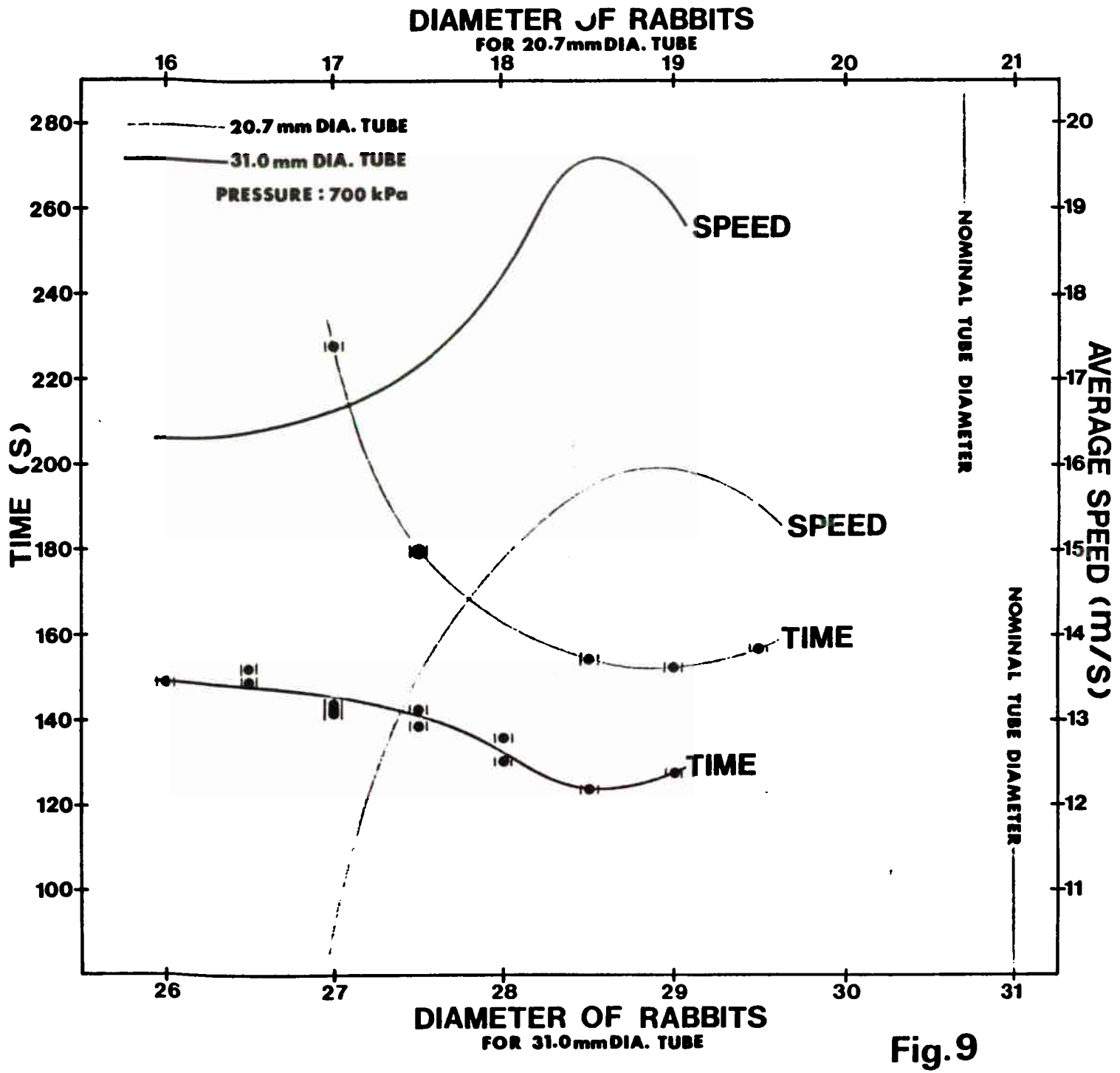

DIAMETER OF RABBITS
FOR 20.7mm DIA. TUBE
16
17
18
19
20
21
20.7 mm DIA. TUBE
31.0 mm DIA. TUBE
PRESSURE : 700 kPa
SPEED
SPEED
TIME
TIME
NOMINAL TUBE DIAMETER
NOMINAL TUBE DIAMETER
TIME (S)
AVERAGE SPEED (m/S)
280
260
240
220
200
180
160
140
120
100
20
19
18
17
16
15
14
13
12
11
26
27
28
29
30
31
DIAMETER OF RABBITS
FOR 31.0mm DIA. TUBE

Fig.9

Variation Of Pressure

THE PRESSURE IN THE TANK SUPPLYING THE AIR TO THE RABBIT LINES WAS REDUCED BY CLOSING THE VALVE TO THE COMPRESSOR.

THIS CAUSED A PRESSURE DROP OF ~200 kPa DURING A RUN. THE EFFECT ON THE TRANSIT TIME IS RELATIVELY MINOR AND IS IGNORED IN FIG. 10.

A 50% INCREASE IN PRESSURE WOULD REDUCE THE TRAVEL TIME BY:

24% FOR THE 20.7 MM DIA. TUBE

40% FOR THE 31.0 MM DIA. TUBE

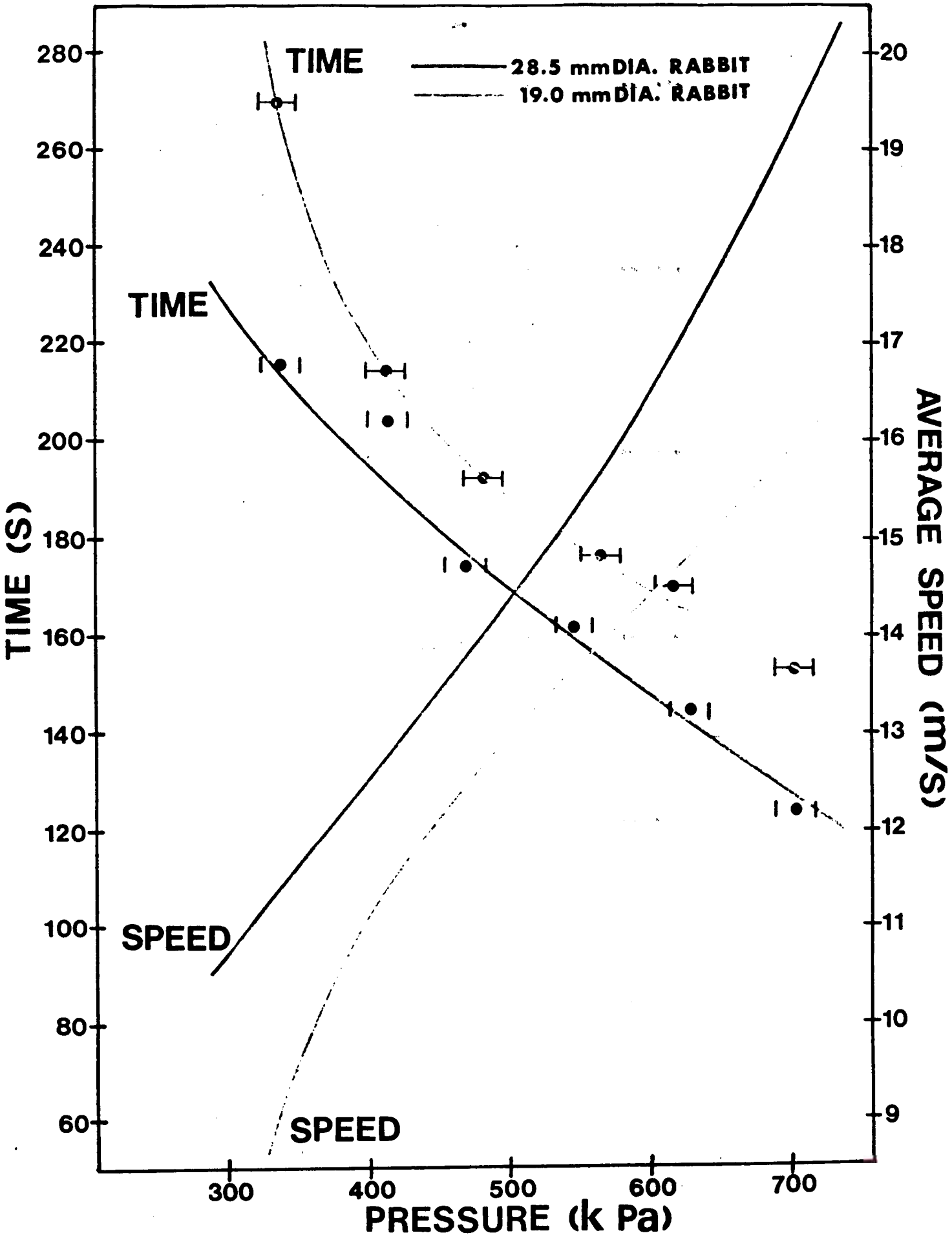

TIME
28.5 mm DIA. RABBIT
19.0 mm DIA. RABBIT
TIME
SPEED
SPEED
TIME (S)
AVERAGE SPEED (m/S)
PRESSURE (k Pa)
280
260
240
220
200
180
160
140
120
100
80
60
20
19
18
17
16
15
14
13
12
11
10
9
300
400
500
600
700

Fig. 10

Variation Of Tube Length

TUBE LENGTH WAS VARIED BY DISCONNECTING THE COUPLINGS IN SOME MANHOLES.

FIG. 11 SHOWS THAT THE LENGTH OF THE TUBE HAS LITTLE EFFECT ON THE INITIAL SPEED.

FIG. 12 SHOWS TRANSIT TIME T AND AVERAGE SPEED $\bar{S}$ VS. THE LENGTH L OF THE TUBE.

FIG. 13 SHOWS LOG T VS. LOG L. THE GRAPH INDICATES THAT, WITHIN THE RANGE MEASURED, T VARIES WITH L AS $L^{1.5}$.

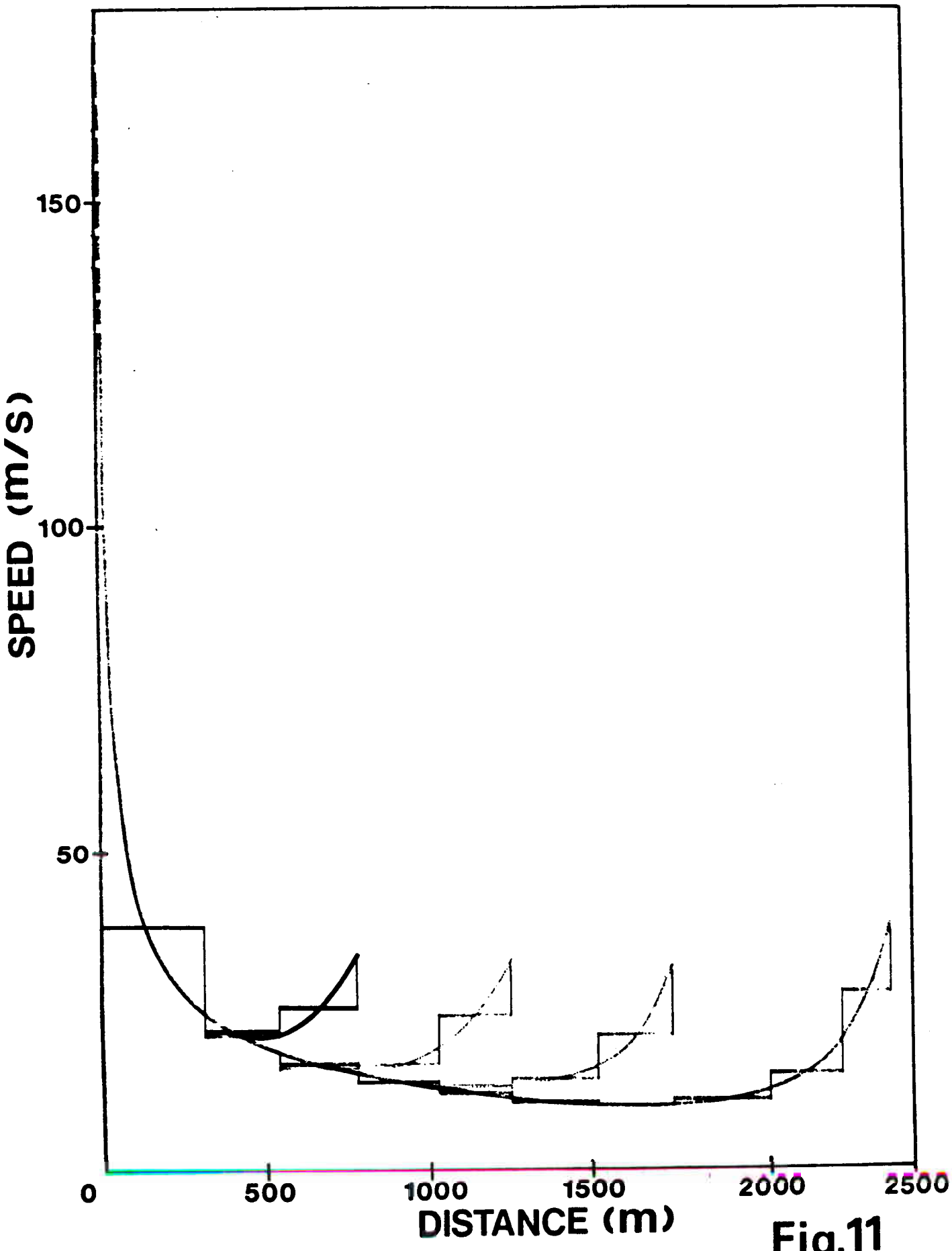


Fig.11

CONDITIONS FOR Fig.11,12 & 13

NOMINAL TUBE DIAMETER: 20.7mm

RABBIT DIAMETER: 18.5 mm

PRESSURE: 700 kPa

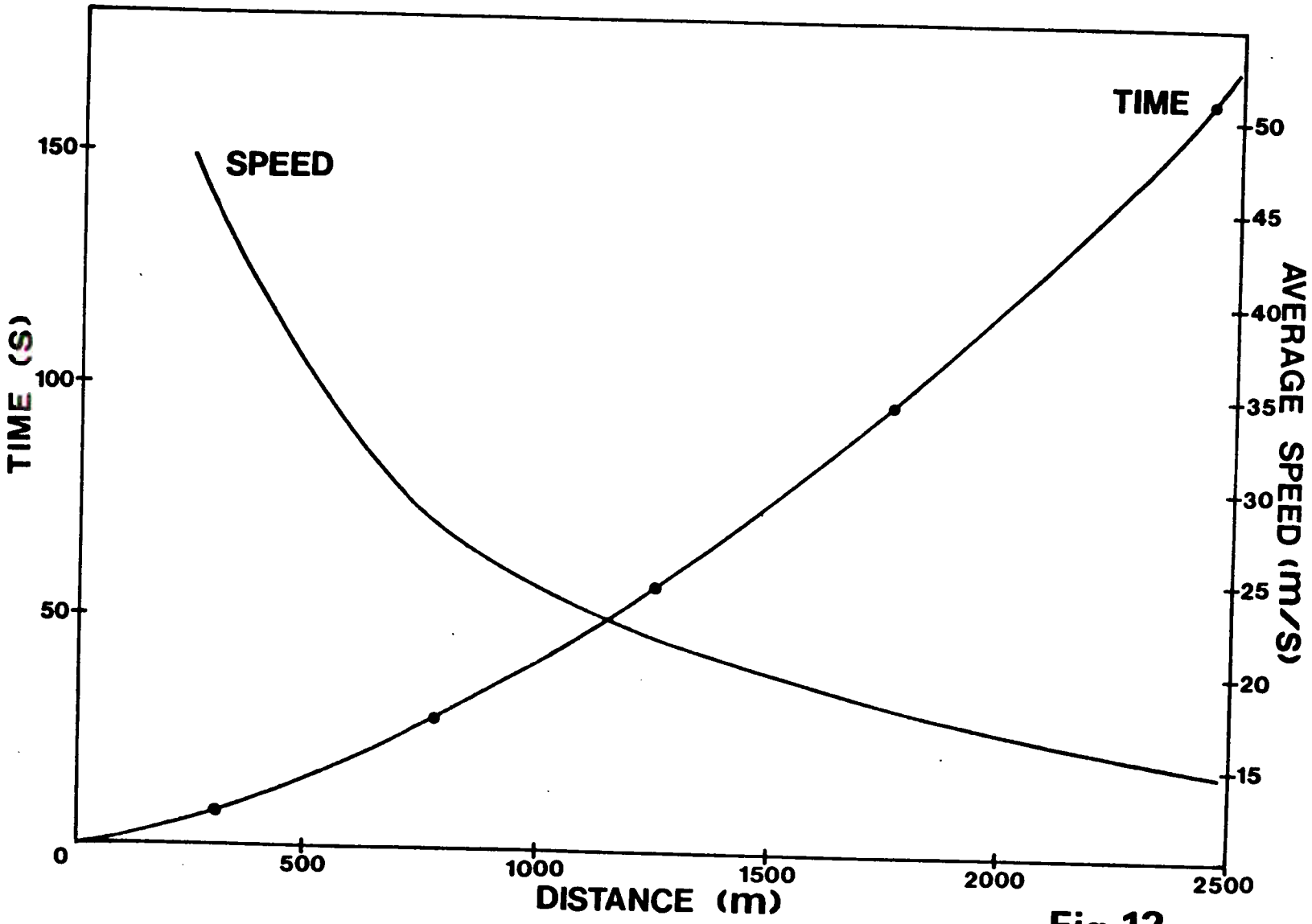


Fig. 12

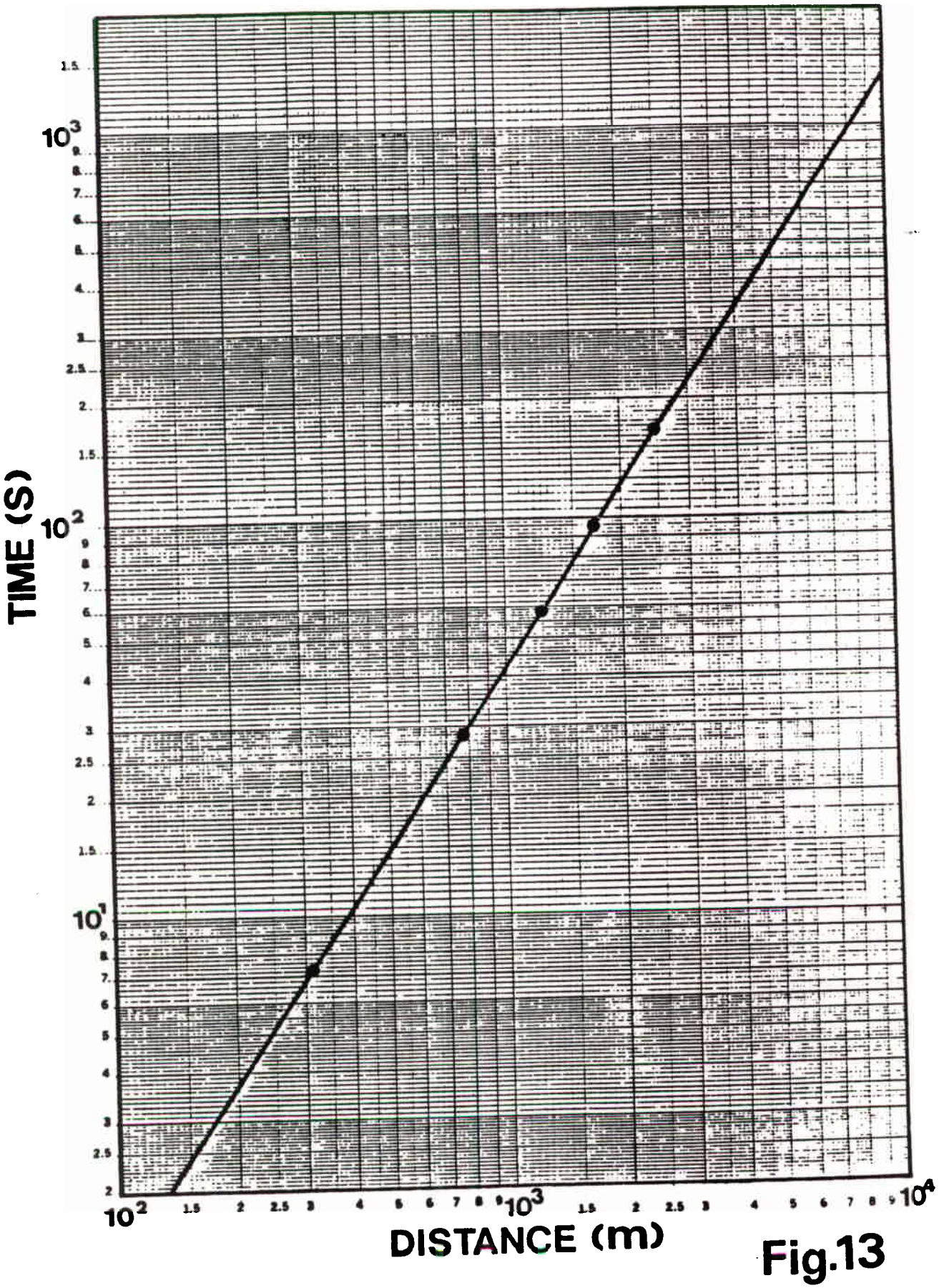


Fig.13

Conclusions

1. Both prototype tests and "as built" test prove that rabbits can be transferred over 2.4 km in 2 - 2.5 minutes in tubes of 31.0 and 20.7 mm inside diameter, respectively (Fig. 6).

2. Meeting the design criteria with longer tubes would soon become impractical with this method, as the transit time varies with $L^{1.5}$ (Fig. 13).

3. The theoretical minimum transit time for a 20.7 I.D. rabbit tube of 2.4 km length is approximately 1 minute, the transit time for the pressure front (Fig. 7). For this the rabbit would have to seal perfectly inside the tube, with very little friction.

4. Tests not described in this paper have shown that variation of rabbit material and shape had no measurable effect on the transit time.