NASA TECHNICAL MEMORANDUM

NASA TM- 88535

EFFECT OF SONIC BOOM ON AVALANCHES. PREPARATION FOR FLIGHT OF A SUPERSONIC JET OVER THE LAVAY VALLEY

M. Schaffar, B. Carrie, P. Amardeil

Translation of "Effet du bang sur les avalanches. Preparation du survol de la vallee de la Lavey par un avion a vitesse supersonique."

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546 DECEMBER 1986

(NASA-TM-88535) EFFECT OF SONIC BOOM ON AVALANCHES. PREPARATION FOR FLIGHT OF A SUPERSONIC JET OVER THE LAVAY VALLEY (National Aeronautics and Space Administration) 37 p CSCL 20A G3/71

N87-15775

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Effect of Sonic Boom on Avalanches
Preparation for Flight of a Supersonic Jet Over the Lavey Valley

M. Schaffar, B. Carrie, P. Amardeil

Introduction

Most of the future flights of commercial supersonic aircraft will take place over oceans. However in case the sonic boom level touches a mountain region covered with snow, one must know what could be the effect of the sonic boom on the avalanches and what are the critical conditions of the snow mantle. /7*

The directorate of research and testing means (DRME) assigned the ASP Laboratory (Special Applications of Physics) of the Grenoble Nuclear Research Center (CENG) in collaboration with the Istres Flight Test Center (CEV) and the Franco-German Institute of Saint Louis, the preparation and implementation of a true scale experiment in the Alps, but with sonic booms 5 to 20 times greater than that of the supersonic Concorde in stabilized flight at 16,000 meters altitude.

The ASP laboratory of the CNG chose for this experiment the Lavey Valley, near St. Christophe-on-Oisans; moreover according to the state of the snow mantle, it will lanunch the operation if the snow conditions are critical.

The CEV of Istres will supply an aircraft of the Mirage III type, which will fly over the Lavey Valley according to a well defined supersonic trajectory.

The contribution of ISL is in the sector of the preparatory phase of the experiment and consists in supplying a set of predictions concerning the trajectory, the focusing lines, the region covered by the sonic boom and the intensity levels of the sonic boom for the entire valley.

*Numbers in the margin indicate pagination of the foreign text.

Before specifying the results of our calculations, we will describe the principle of this experiment and the different conditions required for its success on one hand,on the other hand for the safety of the residents of the region of St. Christophe-on-Oisans.

1. Principle of the Experiment

In critical conditions of the snow cover, a Mirage III aircraft will fly at supersonic speeds and at low altitude over the Lavey Valley. During this flight, two cases may arise:

-an avalanche is started. The experiment is positive; there is no need to check once again the state of the snow cover.

Remarks: However no element is available making it possible to compare efficiency /8 between the sonic boom and the effect of the explosion on the starting of avalanches;

-no avalanche was started: in this case one should recheck the state of the snow cover. If the state of the snow cover is no longer critical, the experiment must be postponed to a more favorable time; if on the contrary the snow cover is still unstable, the ASP Laboratory will try to start artificially the avalanches by classical means (explosives).

Two cases may then occur:

-an avalanche is started by the detonation of explosive charge; one may then draw the favorable conclusion that the sonic boom of given intensity is insufficient to start an avalanche;

-if the explosive has no effect, no conclusion can be drawn.

It may finally be noted that a clear answer can only be obtained in the following two cases:

-an avalanche is started by the sonic boom and then the experiment is positive;

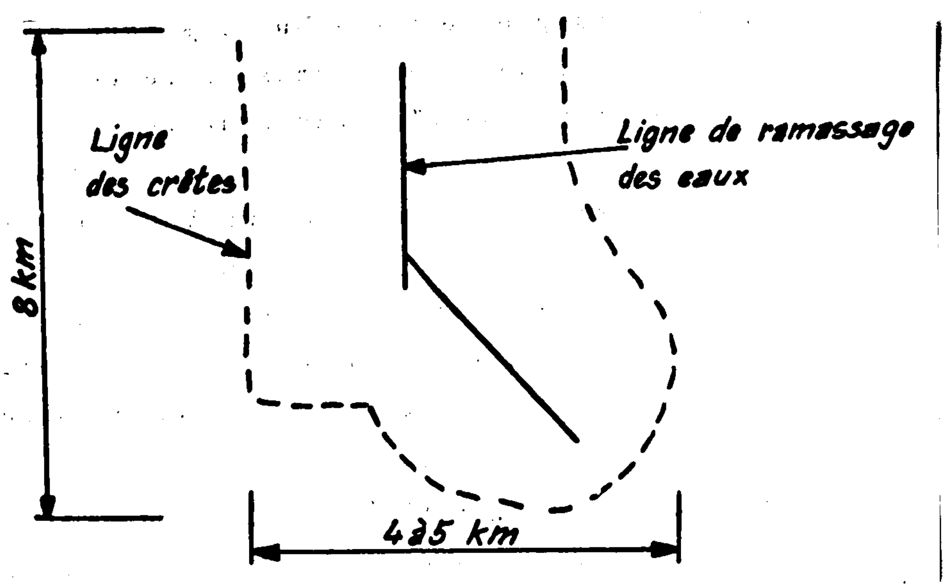
-nothing happens when the plane passes and it is explosive which starts the avalanche.

Finally several passages will be needed to confirm either case.

2. Presentation of the Lavey Valley

2.1 The Lavey Valley is located near St. Christophe-on-Oisans, in the Isere department and in a relatively deserted region (8 inhabitants for the valleys of St. Christophe and Champhorent). The valley itself apart from the Lavey Shelter is deserted as well as the two lateral valleys. Another inhabited region is located beyond the terminal circular valley: this is the higher valley of Valgaudemar (municipalities of Clemence d'Ambel and the Guillaume Peyrouse).

The axis of the valley is oriented practically along the norht-south direction, with the entrance of the valley toward the north and the terminal and the circular portion at the south; the bottom of the valley or water collection line is not totally straight and has around the middle a change in direction toward the east, according to the following scheme: /9



Key: line of the ridges water collection lines

4 to 5 km

The length of the valley is about 8 km and its width 4 to 5 km; the ridges limited to the valley are staggered between 3,000 and 3,500 meters altitude.

2.2 Regions of starting of avalanches

The attentive examination of the relief and the natural avalanches led us to saying:

-the avalanches of powdered snow caused by overloading the snow cover may occur from ridges located between 3,000 and 3,500 meters altitude and more especially on the Aiguille de l'OLAN.

-The "spring" avalanches may start at the lower altitude, between 2500 and 3000 m.

-Moreover snow slides may arise anytime between 1800 and 2200m.

2.3 At the center of the Lavey Valley a shelter may be found, accessible in winter. The ASP Laboratory may make measurements of intensity of the sonic boom near this shelter. The installation of the transducers is shown on fig. 1; ten transducers have been planned, including among them two transducers meant for /10
measuring the penetration of the sonic boom into the snow layer.

From the measurements of sonic boom carried out near the shelter, it should be possible to determine the level of the sonic boom in the rest of the valley, since the latter includes no other easily accessible places favorable to measurements by classical means. A measurement technique by remote measurement, perfected by ISL, may possibly remedy these drawbacks, but this technique nust be perfected for the very special conditions of this experiment. This adjustment might be implemented during summer if an experiment is organized to carry out measurements of several points.

3. Conditions Relating to Safety and Success of the Experiment

Since it is forbidden to fly over the Alps at supersonic speed and at low altitudes, one must make sure that the region covered by the sonic boom does not exdeed the limits into the inhabited valleys which adjoin the Lavey Valley, so as not to create risks for the inhabitants for these valleys. The small size of the valley then requires an accelerated, relatively short and low altitude flight.

However the main regions of starting of avalanches are under the ridges and for the experiment to be thorough, the region covered by the sonic boom must go up to below the ridges, between 2900 and 3500 m.

The ASP Laboratory, as we specified in the previous paragraph, will carry out measurements of sonic boom near the shelter. To guarantee a good representativeness of these measurements, the focusing line caused by the accelerated flight must be in front of the shelter, 300 to 500 m maximum, so that the boom should have already stabilized at the level of the shelter.

Because of the narrowness of this valley, these different conditions are rather difficult to satisfy. The maneuvering margin is narrower because we also have to take into account the risks incurred by the pilot carrying out the flight (low altitude, slightly supersonic speed, unstable aircraft).

4. Direction of Flight and Trajectory /11

4.1 Direction of Flight

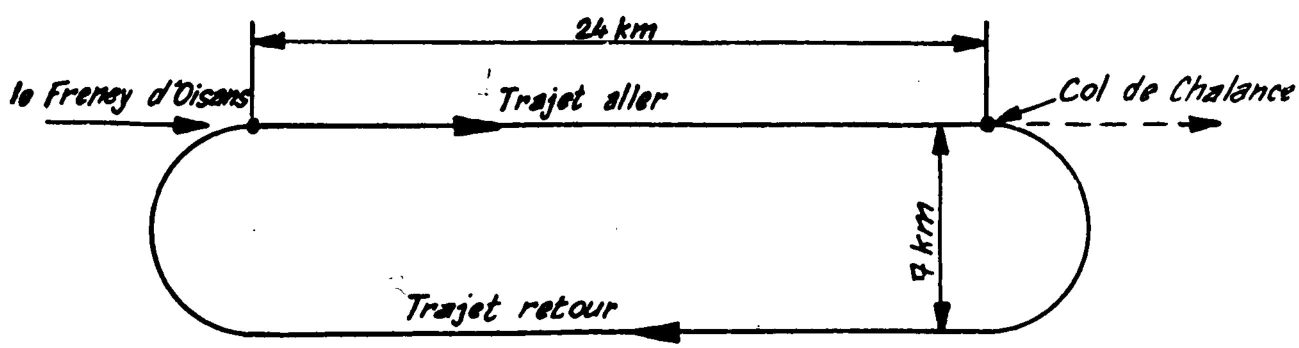
To ensure a proper implementation of the experiment, the flight direction must be easily noted by the aircraft; moreover this direction must follow as well as possible the direction of the valley to guarantee its certain symmetry of the region covered by the sonic boom with regard to the relief of the valley.

With the configuration of the valley, two rather close flight directions are possible, and it should be specified here that in our calculations we only took into account the first:

1) Straight line connecting the Clot d'en Haut to the Col de Chalance (3010 m).

2) Straight line connecting Sanchey-Chalet and the Col de Chalance.

The flight direction chosen will be integrated in a complete circuit, proposed by the CEV, a circuit whose grand projection has the shape of a hippodrome.



Key: 1. forward flight
2. return flight

4.2 Trajectory

With the previously defined conditions and taking into account the performances of the aircraft in the slightly supersonic sector, a trajectory was defined at a meeting of the ISL with CEV and the ASP Laboratory on December 1, 1971.

Preliminary calculations with this trajectory and variants have not been satisfactory, either because the region covered by the sonic boom was too small, or the focusing line was after the shelter.

The trajectory which we finally retained shown on fig. 2 is as follows: /12

-Departure: Tete de Toura at 3525 m altitude;

-dive of $-6^{0}20'$ to reach $M = 0.96$ and at the altitude 3300 m the vertical of Combe du Sec, located about 600 m after St. Christophe-on-Oisans;

-beginning of acceleration of 3 m/s^2 in Combe du Sec, at $t = 0$ with the same angle of dives as before;

-beginning of resource under 3 g at constant velocity, after 15 s acclerated flight (minimum altitude 2700 m). The resource at constant speed will continue until the incidence is $+ 45^{0}$;

-deceleration of of 3 m/s^2 with an incidence of $+ 45^{0}$ until the speed becomes subsonic again.

The trajectory thus defined is satisfactory as long as the pilot manages to follow it rather precisely.

5. Results of Calculations

5.1 Preliminary remark and qualitative effects of an inversion of the temperture gradients

All our calculations were carried out in standard atmosphere, with the following law of variation of sound:

$$a = \sqrt{\gamma r \lambda (H-z)} \quad \text{with} \quad \begin{cases} H = 44\ 332 \text{ m} \\ \lambda = 6{,}5 \cdot 10^{-3} \text{ degrees/m} \\ r = 287 \\ \gamma = 1{,}405 \end{cases}$$

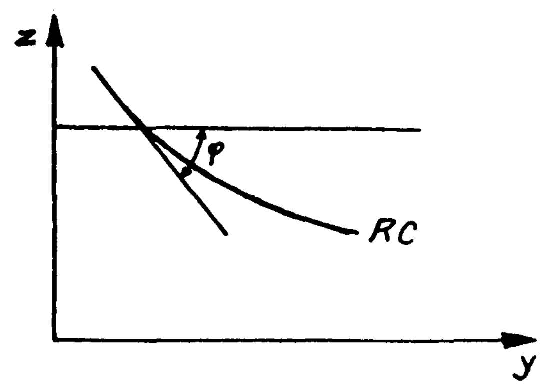
z in meters

Therefore we did not take into account a possible inversion of the temperature gradient, an inversion which may possibly occur in spring (cold on the ground and warmer in altitude).

The possible consequences on the characteristic beams can be examined quantitatively by means of the law of propogation of these beams which is none other than the Descartes relationship (horizontal plane diopter):

$$\frac{a}{\cos\varphi} = Cte$$ /13

where a is the velocity of sound and φ the angle of the tangent to the characteristic beam with the horizontal direction.



In the normal case in standard atmosphere, a beam emitted under the trajectory downward will curve to form a tangent to the horizontal plane and then rise again unless it has touched the ground and a beam emitted upwards will tend to become increasingly vertical.

If now it is assumed that a beam emitted downward should meet an atmosphere whose down, the angle φ of this beam according to the Descartes relationships will tend to encrease and the beam will approach the vertical line. This phenomenon may then bring the focusing line near the starting point of the trajectory, which in principle should not effect much the results of our calculations.

For a beam emitted upward in an atmosphere which is being heated up, the effect will be contrary. This beam will tend to curve towards a horizontal inset of a vertical as in the normal case. In this case there is practically no overflow for lateral valleys, but the sonic boom may overflow into the higher valley of Valgaudemar. Actually certain beams, emitted almost horizontally may be brought by the inversion of temperature into the valley of Valgaudemar and thus a sonic boom even a very low intensity could be felt there as will be seen in the following paragraph.

Finally to evaluate the possible consequences of a temperature inversion, one should have an order of magnitude of the extent of the inversion phenomenon (temperture deviation and altitude region effected).

5.2 Maximum region covered by the sonic boom

The determination of this region may be carried out:

-either by a method which follows each characteristic beam (ARAP program of Hayes); then the question is to place the interaction of this beam with the relief;

-either by calculating the intersection of the Mach conoids with vertical planes orthogonal to the trajectory. /14

For the maximum region covered by the sonic boom, the second method is clearly more practical.

The figures 5 to 15 show the intersections of Mach conoids with different vertical planes; it should be specified that we did not take into consideration the fact that certain beams might be stopped during their propogation by the mountain overhang.

On the whole of figures 5 to 13, the following remarks may be made:

-most of the beams considered of these figures are beams emitted above the trajectory;

-we note a focusing of the characteristic beams on the slopes between 2900 and 3300 m altitude, which will increase locally the level of the sonic boom under the ridges, therefore in the avalanche region;

-on fig. 13, the overflow of the beam, shown in dotted line, is not real; this overflow is not possible, because the beams have already touched the ground before the plane located at 11 km.

The maximum region covered by the sonic boom is shown concretely on the map fig. 4 by a dashed line.

Laterally this region goes up to under the ridges; moreover the entire terminal circular valley is touched by the characteristic beam, of which certain may go beyond the ridge line. This overflow which incurs no risk in the normal case may however cause low intensity sonic boom in the valley located beyond the terminal circular valley, is the case of a considerable temperature conversion.

5.3 Level of the sonic boom and focusing line

The Hayes ARAP program only allows the level of the sonic boom to be calculated for the region covered by the rays emitted by the trajectory; moreover for this program we must know the Witham F function of Mirage III aircraft. This is the function which takes into account the shape of the aircraft and the different drag and bearing coefficient. Since this information is not available, we use the F function given in the literature for Starfighter, an aircraft of the same class as the Mirage III but of different shape, which however should not effect greatly the intensity of calculating sonic booms.

Finally in our results we introduced the normal ground reflection factor, that is 2, because the exact value of the reflection factor on a snow covered ground is not known. /15

5.3.1 Characteristic rays under track

Figure 3 shows a cross section of the relief uner track, the trajectory noted in time and in Mach, the caustic surface and a series of characteristic rays emmitted under the trajectory.

These rays, converging near the caustic surface, then diverge slightly at the level of the shelter and strongly in the terminal circular valleys; the last ray draw is practically horizontal. The rays emitted during the ascending part of the trajectory diverge even more and are sharply ascending. At the level of the shelter the sonic boom will be already stabilized and the measurements carried out by the ASP Laboratory will be of a highly representative nature on condition that the focusing is placed properly.

5.3.2 Focusing line

The focusing line visible at fig. 3 has the shape of a circular arc and is placed clearly before the shelter; it is 500 m away at the nearest point.

But it should be specified that the position of this line is a function of the precision with which the pilot can execute the trajectory which we define; if the starting of this acceleration takes place before the Combe du Sec, the focusing line will be further removed from the shelter, which will hardly have any effect on the success of the experiment. If on the contrary the accelerated phase of the trajectory starts after Combe du Sec, the focusing line will be closer to the shelter, which might disturb the measurements of sonic boom carried out by the ASP Laboratory.

Meanwhile in inversion of the temperature gradient as was described in paragraph 5.1 can also effect the position of the focusing line and the extent of the region covered by the sonic boom.

5.3.3 Intensity of the sonic boom /16

It was possible to calculate exactly the sonic boom only for the region covered by the rays emitted under the trajectory and moreover a focusing of the ascending rays was noted, immediately under the ridges. Then we must expect levels of the following order of magnitude, taking into account the ground reflection:

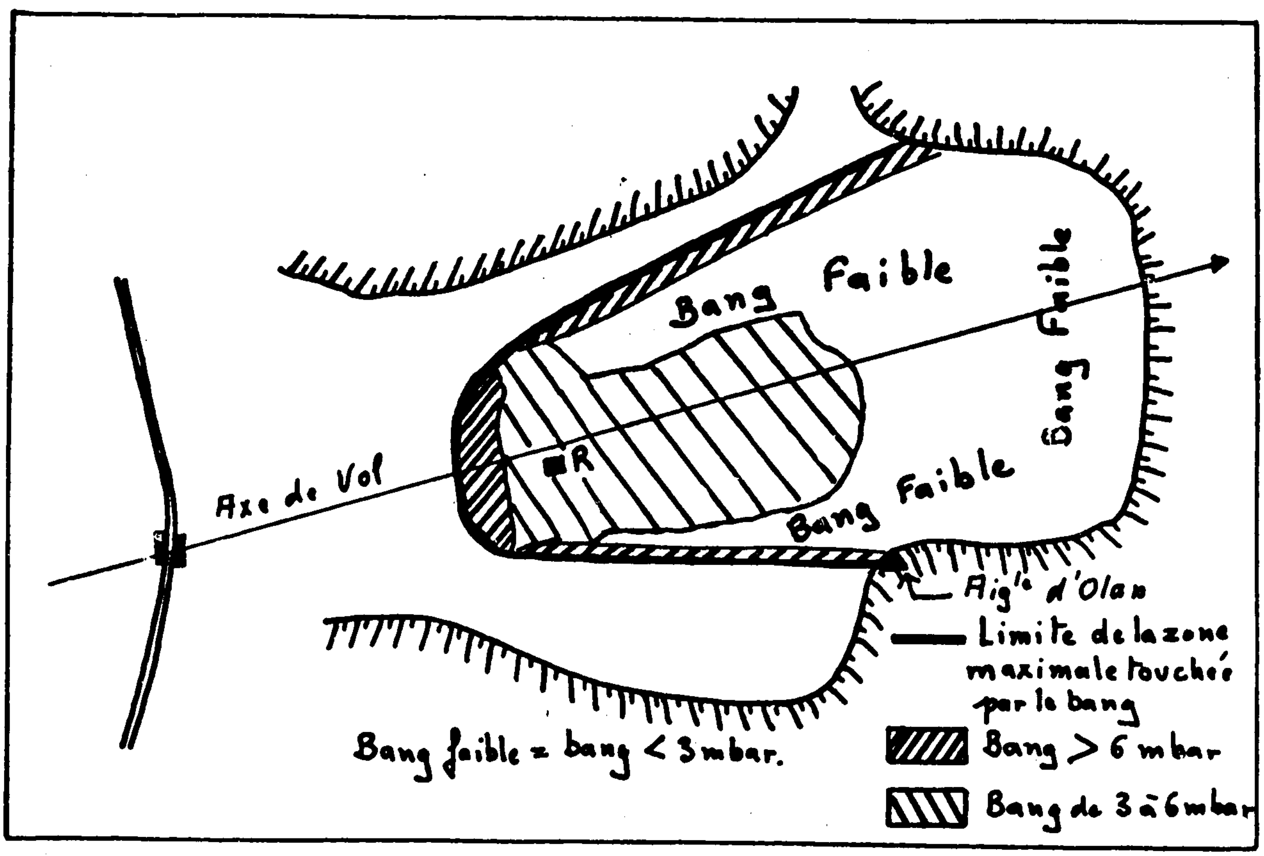
-10 mbars and more near the focusing;

-between 5 and 6 mbars in the immediate vicinity of the shelter;

-between 5 and 10 mbars under the ridges, in places where the ascending rays focus;

-2 mbars and less in the terminal circular valley.

These different regions are shown schematically on the following drawing and the sonic boom levels calculated are shown on the map of fig. 3.



Scheme of the different regions of the sonic boom

Key: 1. flight direction
2. weak sonic boom
3. weak sonic boom = boom < 3 mbars
4. limit of the maximum region covered by the boom
5. boom of 3 to 6 mbars

Meanwhile it may be noted that the sonic boom decreases rather rapidly in intensity under the trace, but laterally the decrease is not rapid. It may also be asserted according to these results that the intensity of the sonic boom which might penetrate into the upper valley of Valgaudemar in the case of an inversion of the temperature -radient will certainly be less than 1 mbar. /17

Conclusion

The calculations which are carried out made it possible for us to predict the broad lines of the experiments of flying over the Lavey Valley with an aircraft at supersonic speed. A trajectory offering maximum chances of success was determined. In normal conditions the region covered by the sonic boom is satisfactory under the aspect of safety and for the success of the experiment. The ridges are exposed to rather localized sonic booms and locally the booms will have an intensity of 10 mbars, that is ten times more than a normal boom.

The shelter will be located in a region of sonic boom of moderate intensity or 5 to 6 mbars, and measurements carried out by the ASP Laboratory can on one hand give an indication about the success of the experiment and on the other be used as a reference point for the sonic boom level in the whole of the valley.

A qualitative study showed that the inversion of the temperature gradient during the flight may have a nonnegligible effect on our calculated predictions and insure sonic booms of low intensity however in the upper valley of Valgaudemar. Moreover in these conditions the sonic boom layer would be more closely restricted in the bottom of the valley, so that there is risk that the experiment might loose its significance, since the ridges are no longer exposed to the boom. But as we do not know the exact atmospheric conditions during the tests, it is impossible to calculate exactly the effects of a temperature inversion.

Finally the execution of one or two flights in summer with measurements of intensity of the sonic boom distribution in all the valleys would be desirable both to check the calculations and to guarantee success of flights in the winter season.

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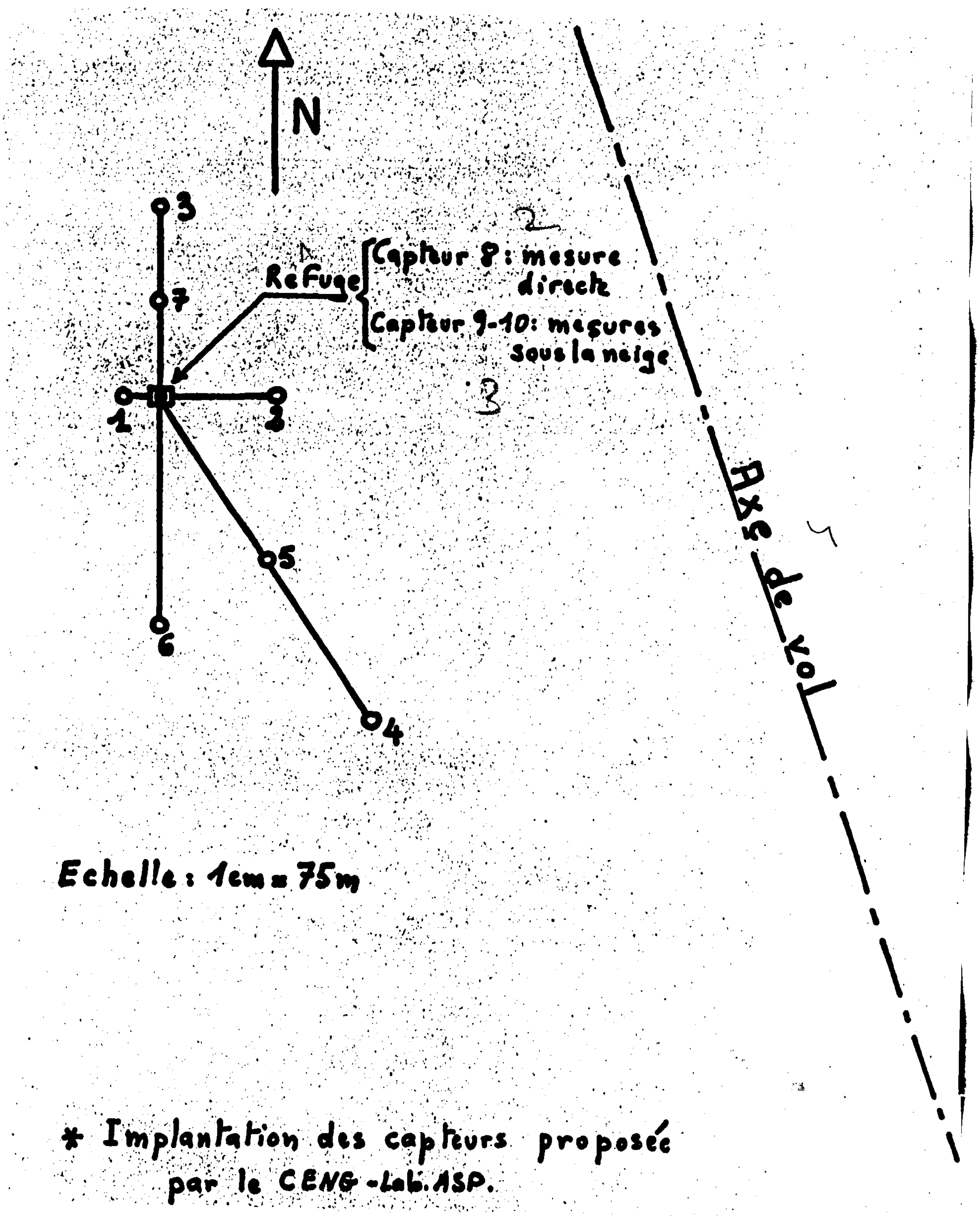


Fig. 1 Sketch of insulation of the transducers*

Key: *insulation of the transducer proposed by CENG-ASP labs.

Scale: 1 cm = 75 m

1. shelter
2. transducer 8: direct measurement
3. transducer 9-10: Measurements under the snow
4. flight direction

Figure 2

Key: 1. Accelerated flight, angle of dive - $6^{0}20'$, acceleration
2. Uniform flight over a circle of 4.4 km radius
3. Trajectory
4. Accelerated flight incidence $+45^{0}$

Figure 3 Direction of flight: Le Clot d'en Haut - Col de Chalence

Key: 1. caustic surface and trace of rays under trace and relief cross section
2. shelter of Lavey

Figure 4 Project of overflight of the Lavey Valley with a supersonic aircraft results of the calculation concerning the region covered by the supersonic boom and level of the boom in different points of the valley

Key: 1. The ascending rays striking the summits between the limits
2. focusing lines
3. limit of the regions touched by the descending rays
4. limit of the region conquered by the ascending rays
5. level of the sonic boom reach of that point, taking into account the ground deflection (calculated with the function F for a Starfighter F104)
6. cross section of the valley according to the planes perpendicular to the trajectory
7. scale

Figure 5

Key: 1. cross section of the valley 6500 m after the starting point of acceleration (500 m in front of the shelter)
2. interaction between the characteristic rays emitted by the aircraft and a vertical plane containing a cross section of the valley
3. the starting of acceleration

Figure 6

Key: 1. cross section 7000 m after starting the acceleration (containing the shelter)
2. starting of acceleration
3. shelter

Figure 7

Key: 1. cross section of the valley 7500 m after the starting of acceleration (500 m after the shelter)
2. starting of acceleration

Figure 8

Key: 1. Cross section of the valley 8600 m after starting acceleration
2. starting of acceleration

Figure 9

Key: 1. Cross section of the valley 9100 m after starting acceleration
2. starting of acceleration

Figure 10

Key: 1. cross section of the valley 9600 m after starting the acceleration
2. starting of acceleration

Figure 11

Key: 1. cross section of the valley 10,000 m after starting the acceleration
2. starting of acceleration

Figure 12

Key: 1. Cross section of the valley 10,400 m after starting acceleration
2. starting of acceleration

Figure 13

Key: 1. cross section of the valley 11,000 m after starting acceleration
2. starting of acceleration

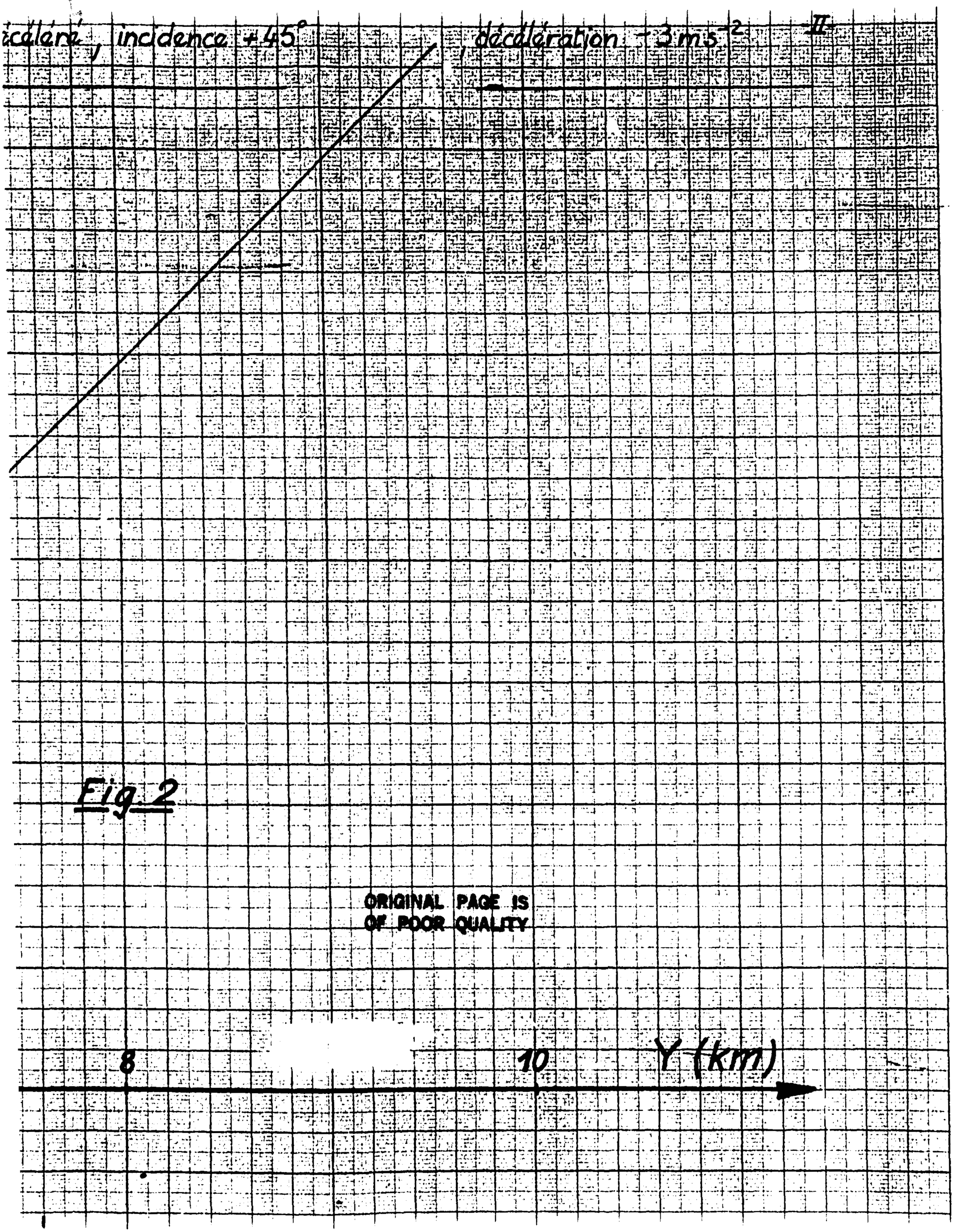
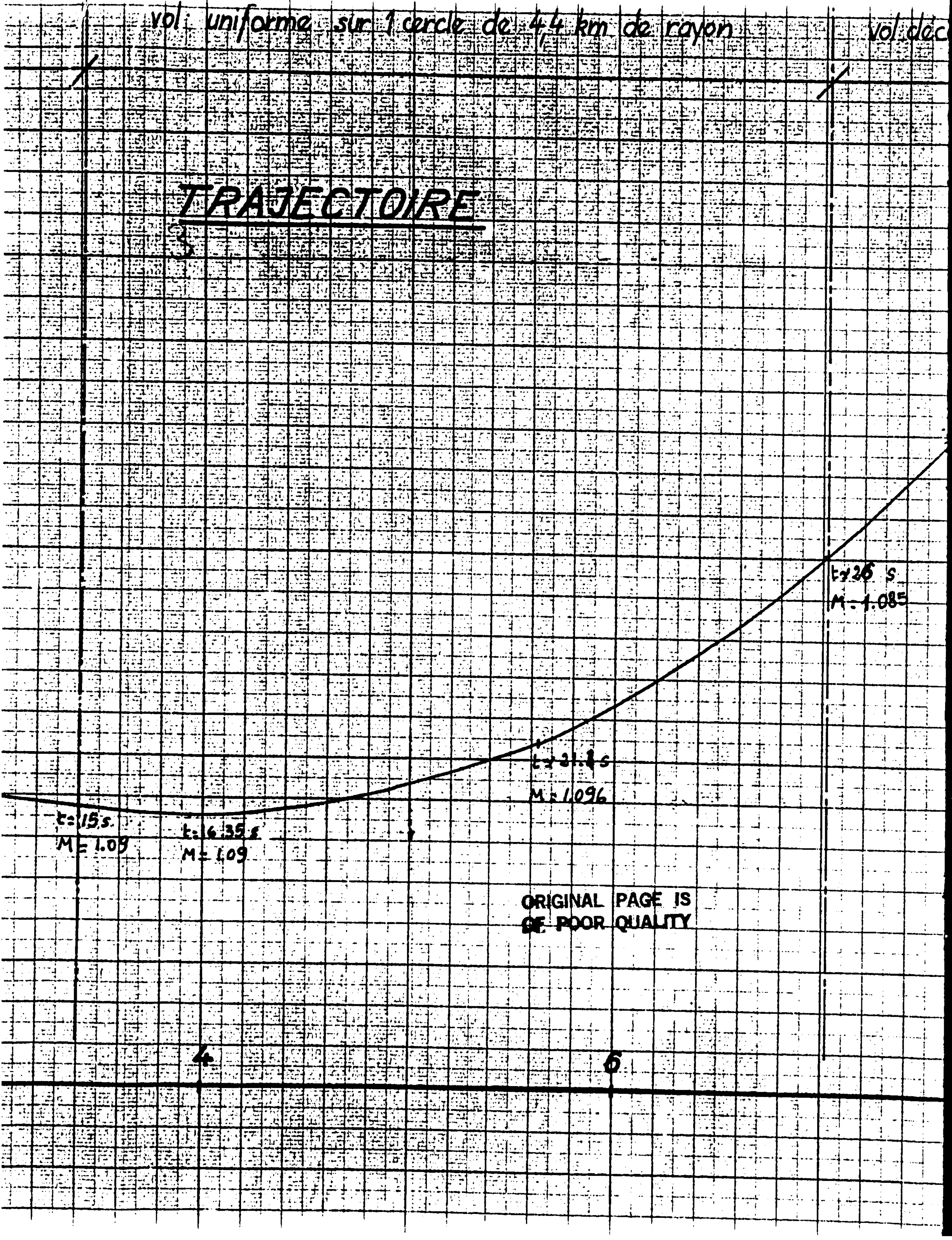
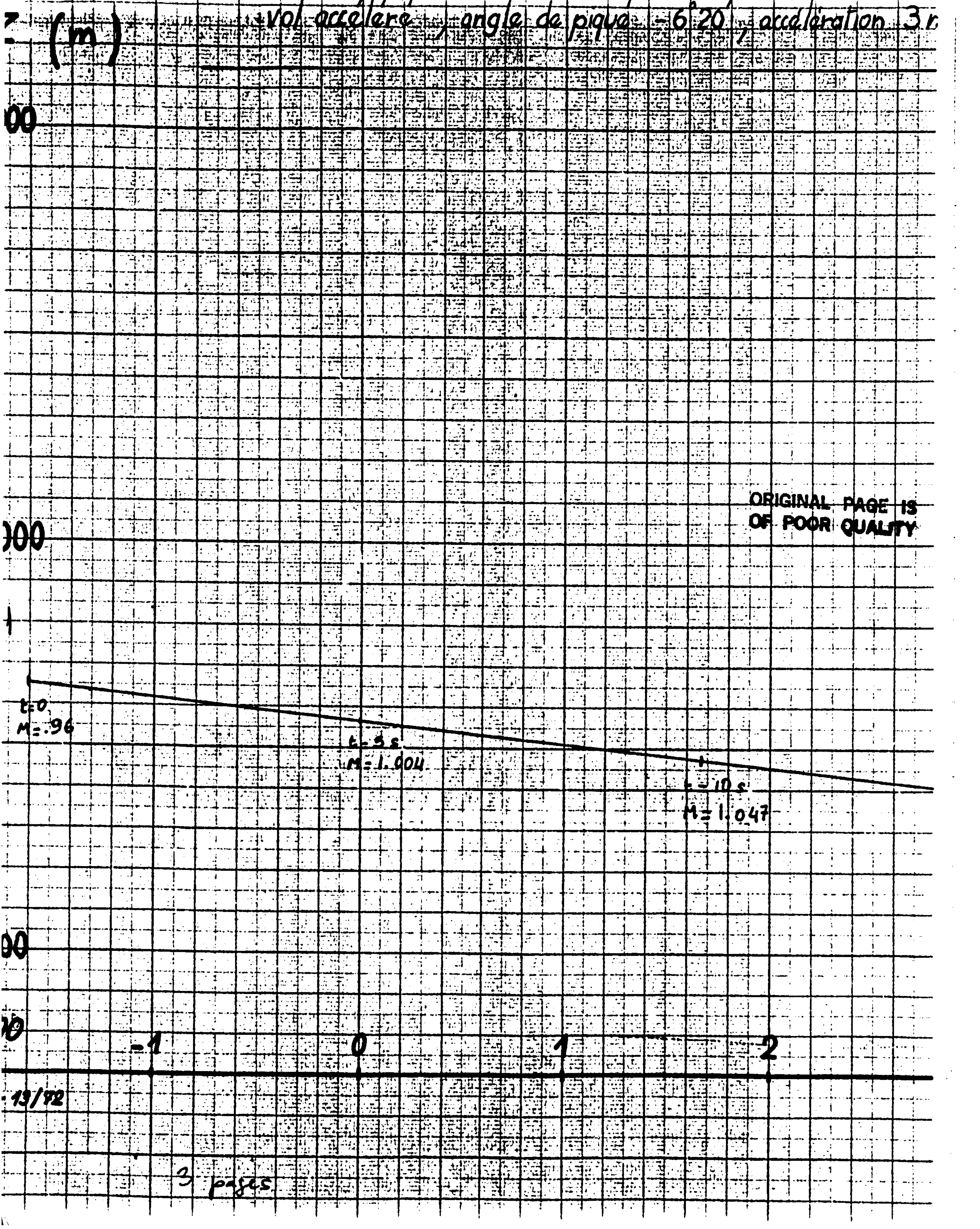


Fig. 2


vol uniforme sur 1 cercle de 4,4 km de rayon
vol déc
TRAJECTOIRE
t = 15 s.
M = 1.09
t = 6.35 s
M = 1.09
M = 1.096
t ≈ 26 s
M = 1.085
4
6


Z (m)
vol accéléré, angle de piqué -6°20', accélération 3
00
000
t=0
M=.96
t=5 s
M=1.004
t=10 s
M=1.047
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2
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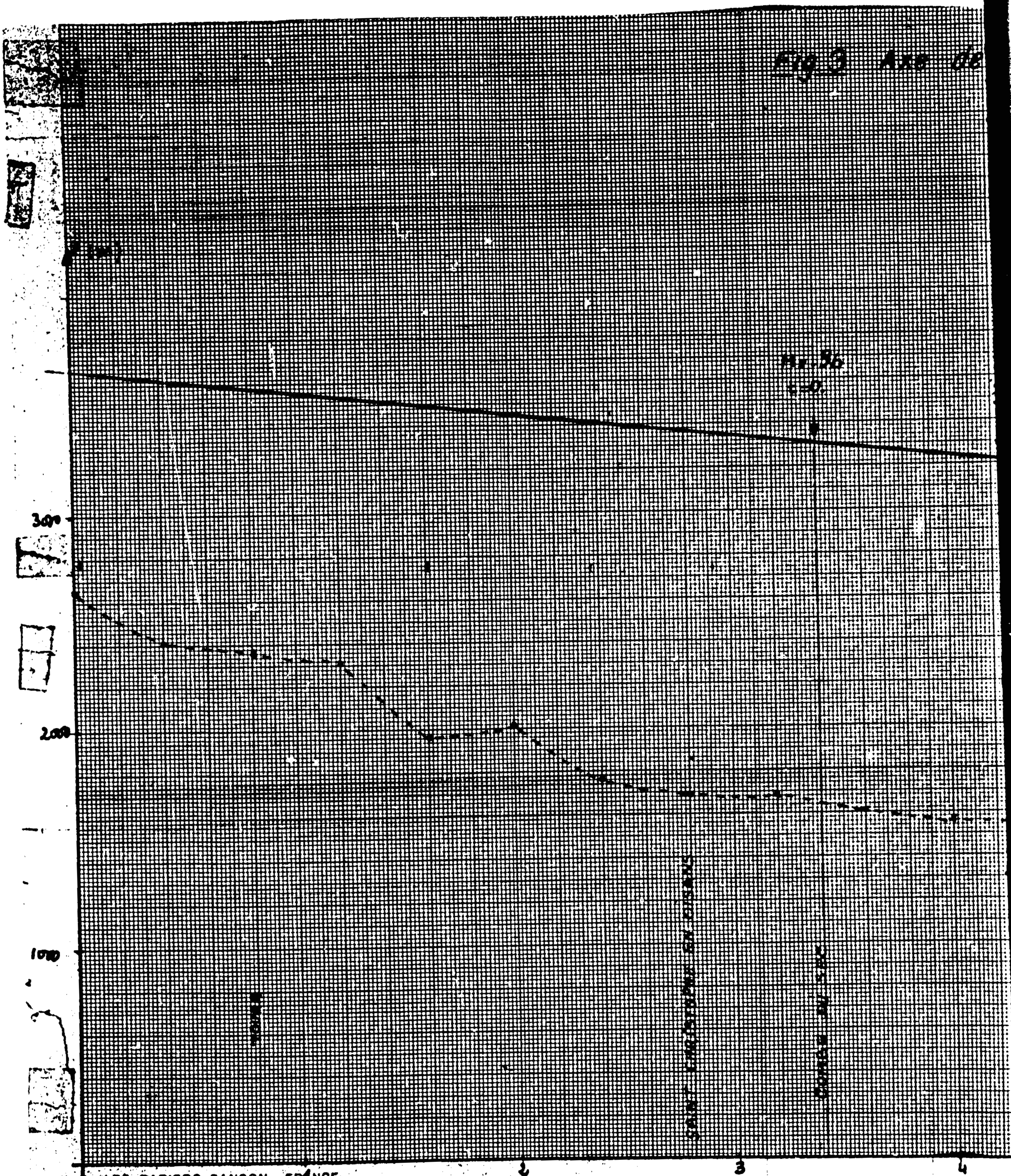

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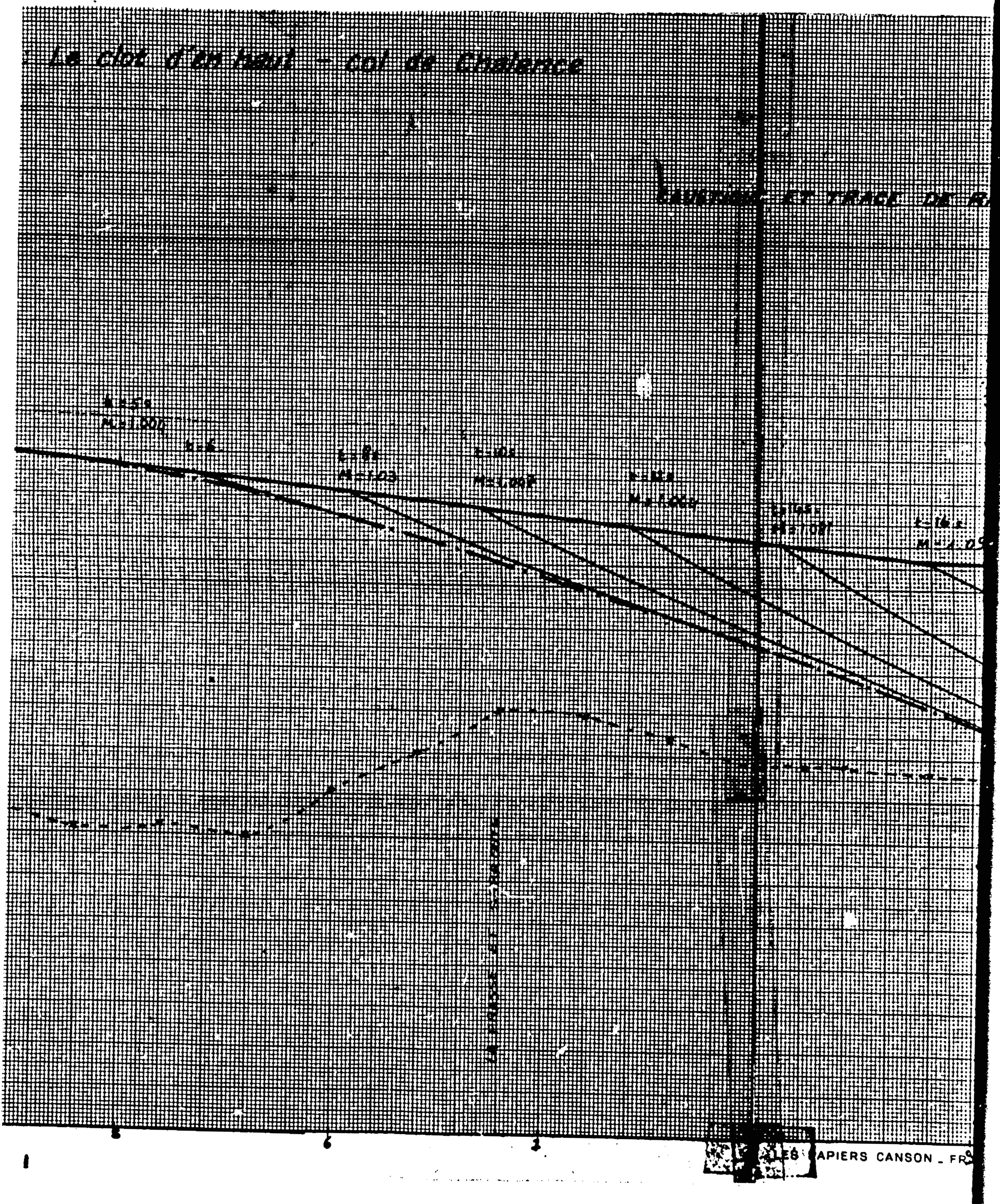
Le clot d'en haut - col de Chalence
CAUSTIQUE ET TRACE DE R
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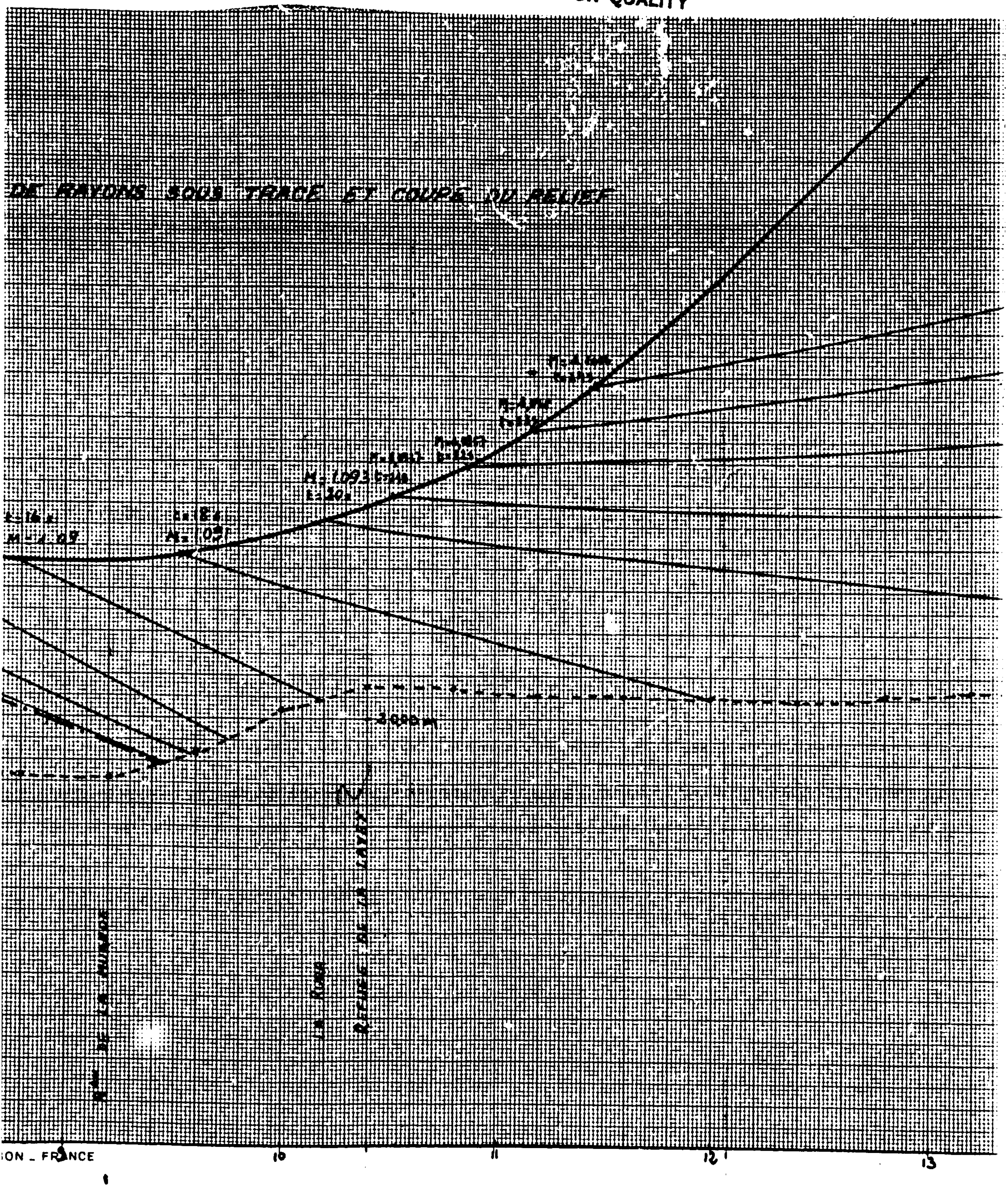

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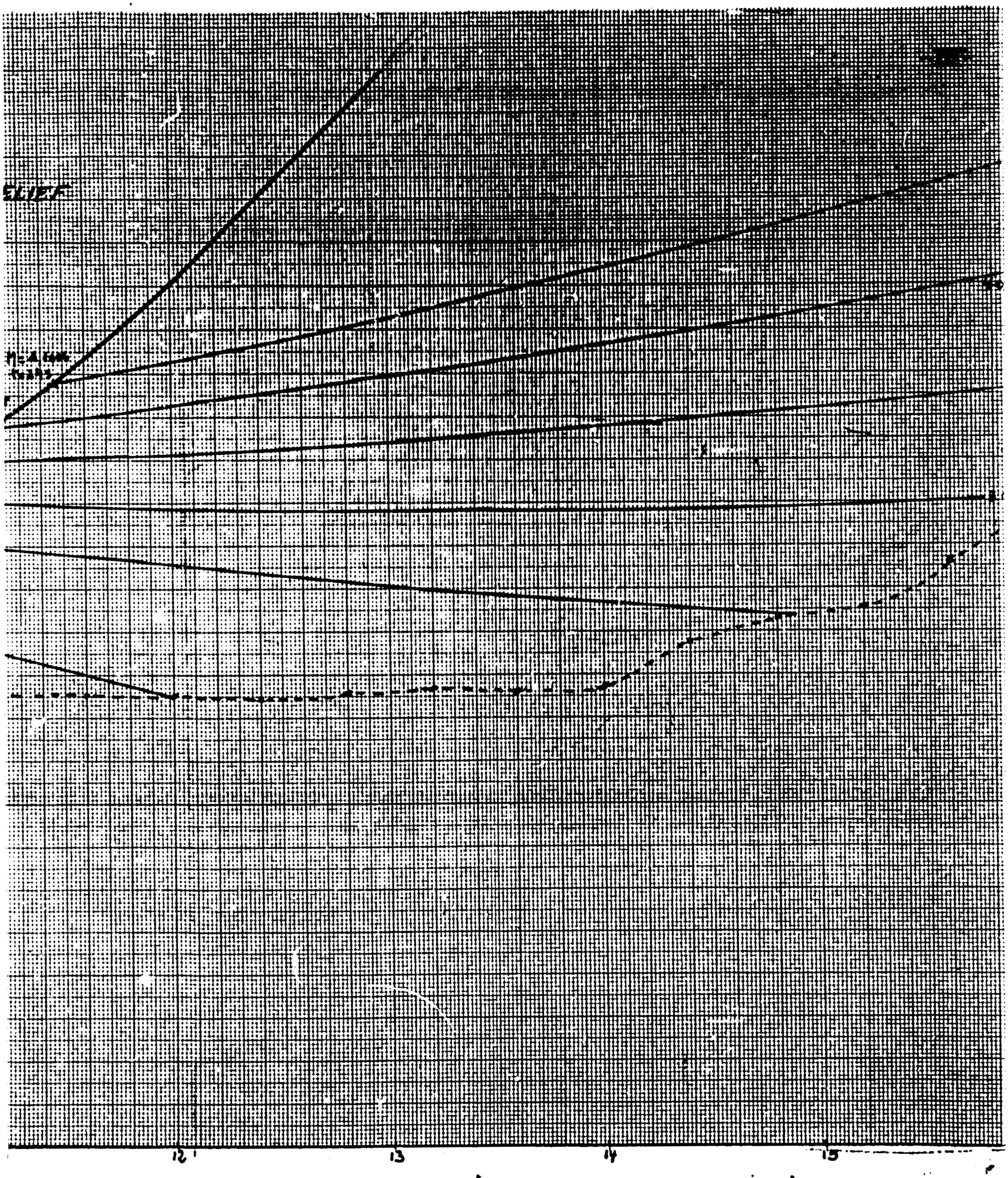

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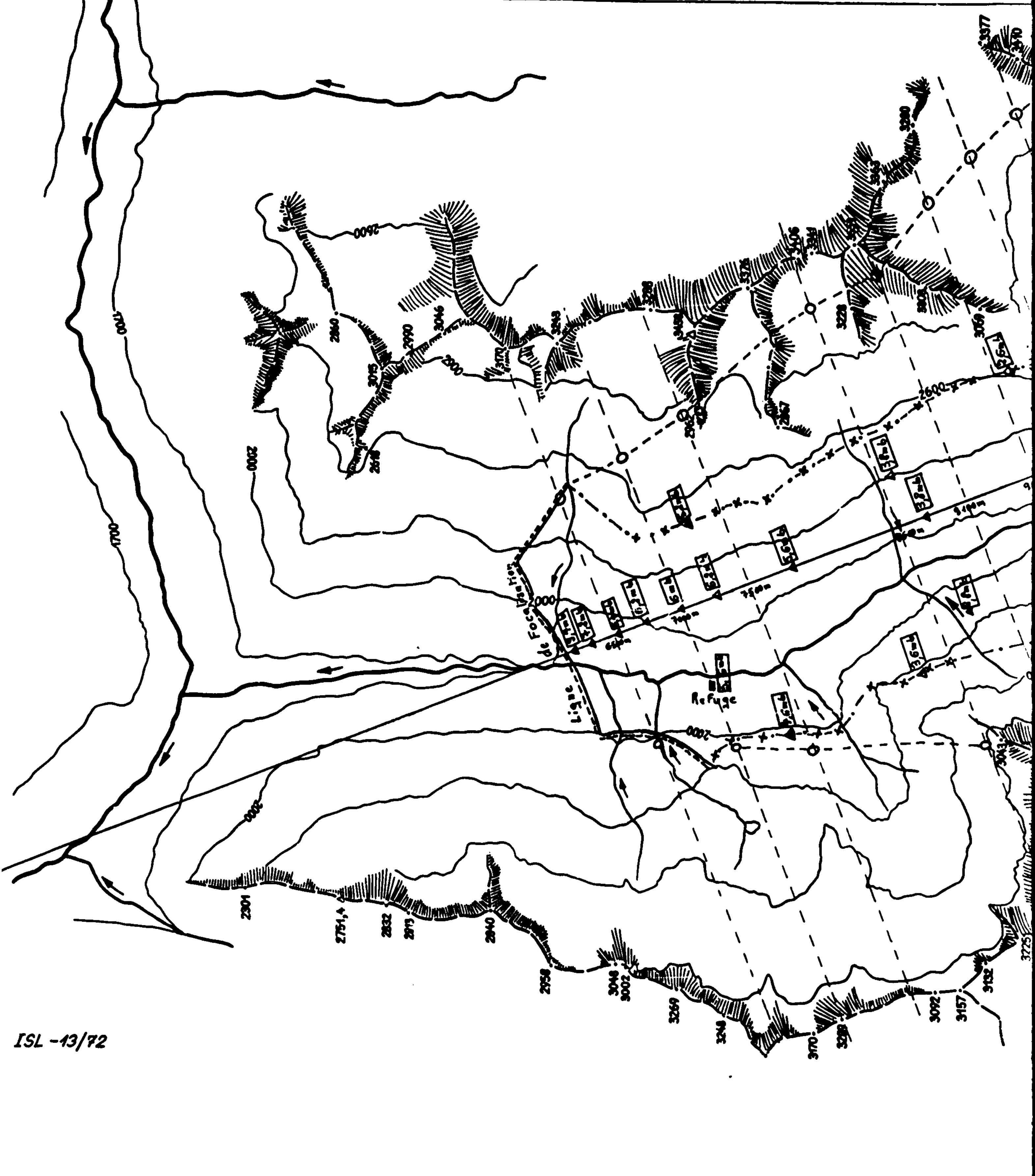
Fig. 4

Projet de survol de la vallée de la LAVEY par un avion s
Résultats du Calcul concernant la zone touchée par le ba
et le niveau du bang en différents points de la vallée.



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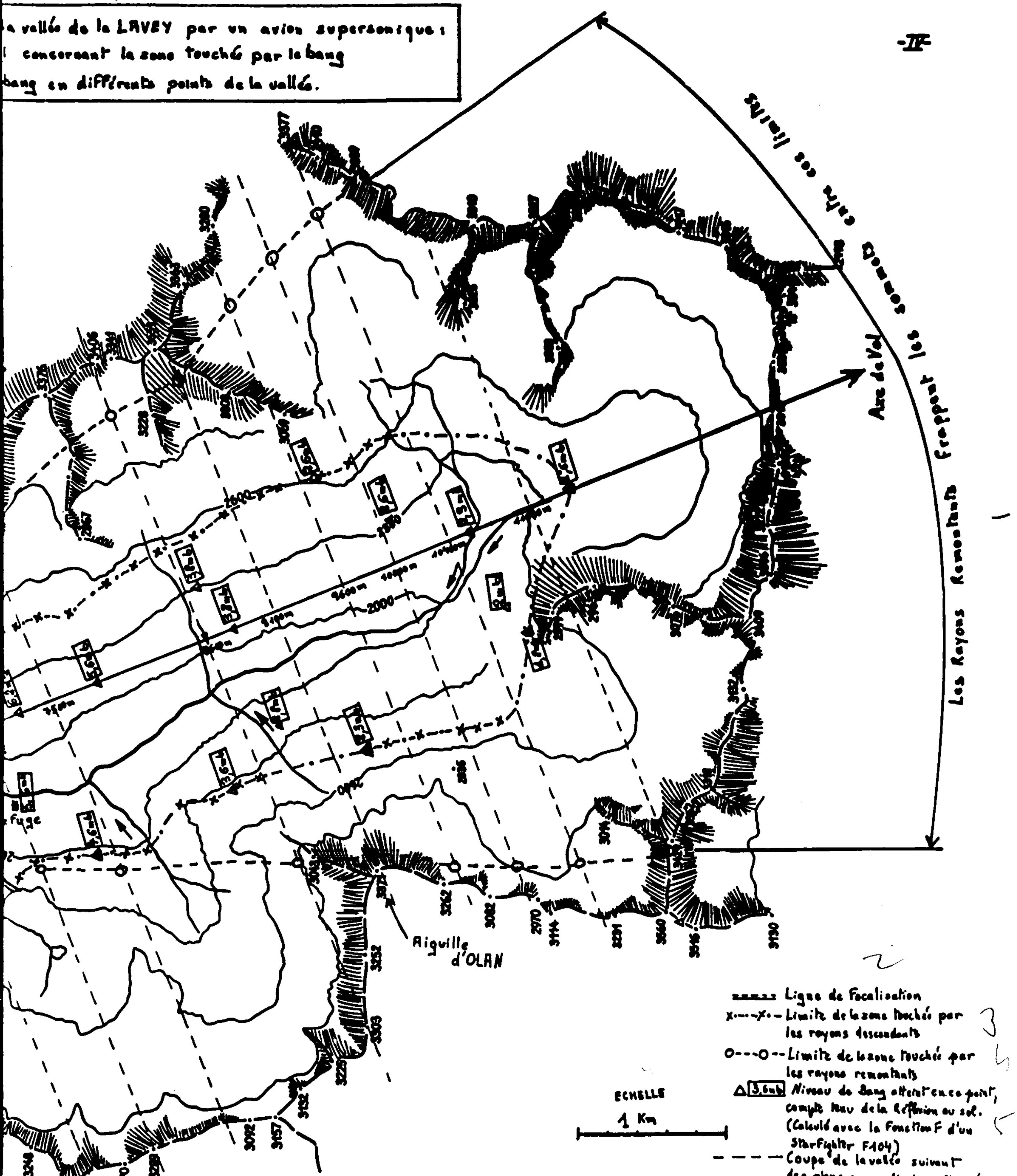
…a vallée de la LAVEY par un avion supersonique :
…l concernant la zone touchée par le bang
…bang en différents points de la vallée.



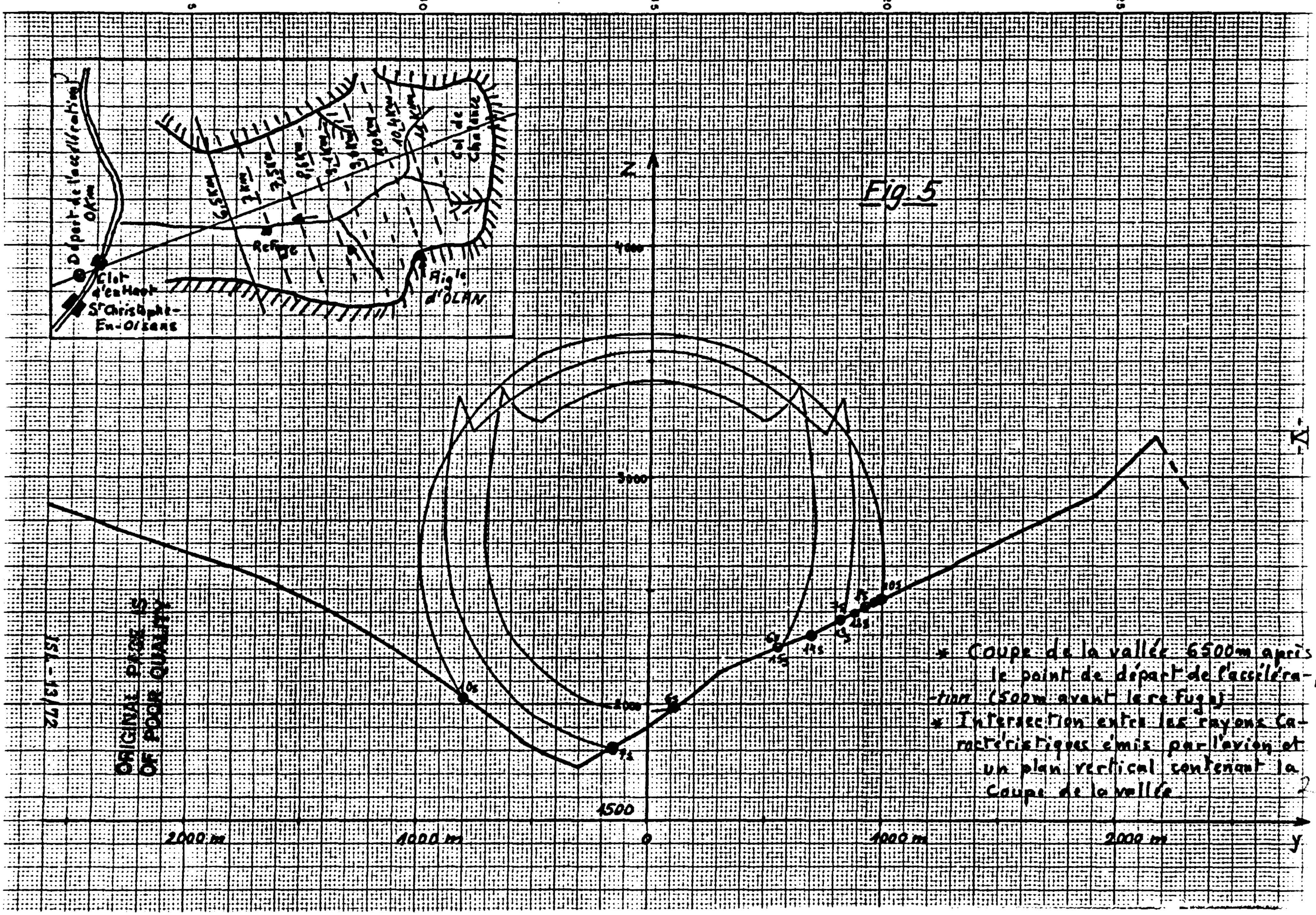


Fig 5
Départ de l'accélération
0 Km
Clot d'en Haut
St Christophe-En-Oisans
6,5 Km
7 Km
7,5 Km
8,5 Km
Refuge
10 Km
10,4 Km
Aigle d'OLAN
Col de Chalance
Z
4000
3000
2000
1500
0
2000 m
1000 m
1000 m
2000 m
Y
* Coupe de la vallée 6500m après le point de départ de l'accélération (500m avant le refuge)
* Intersection entre les rayons caractéristiques émis par l'avion et un plan vertical contenant la coupe de la vallée
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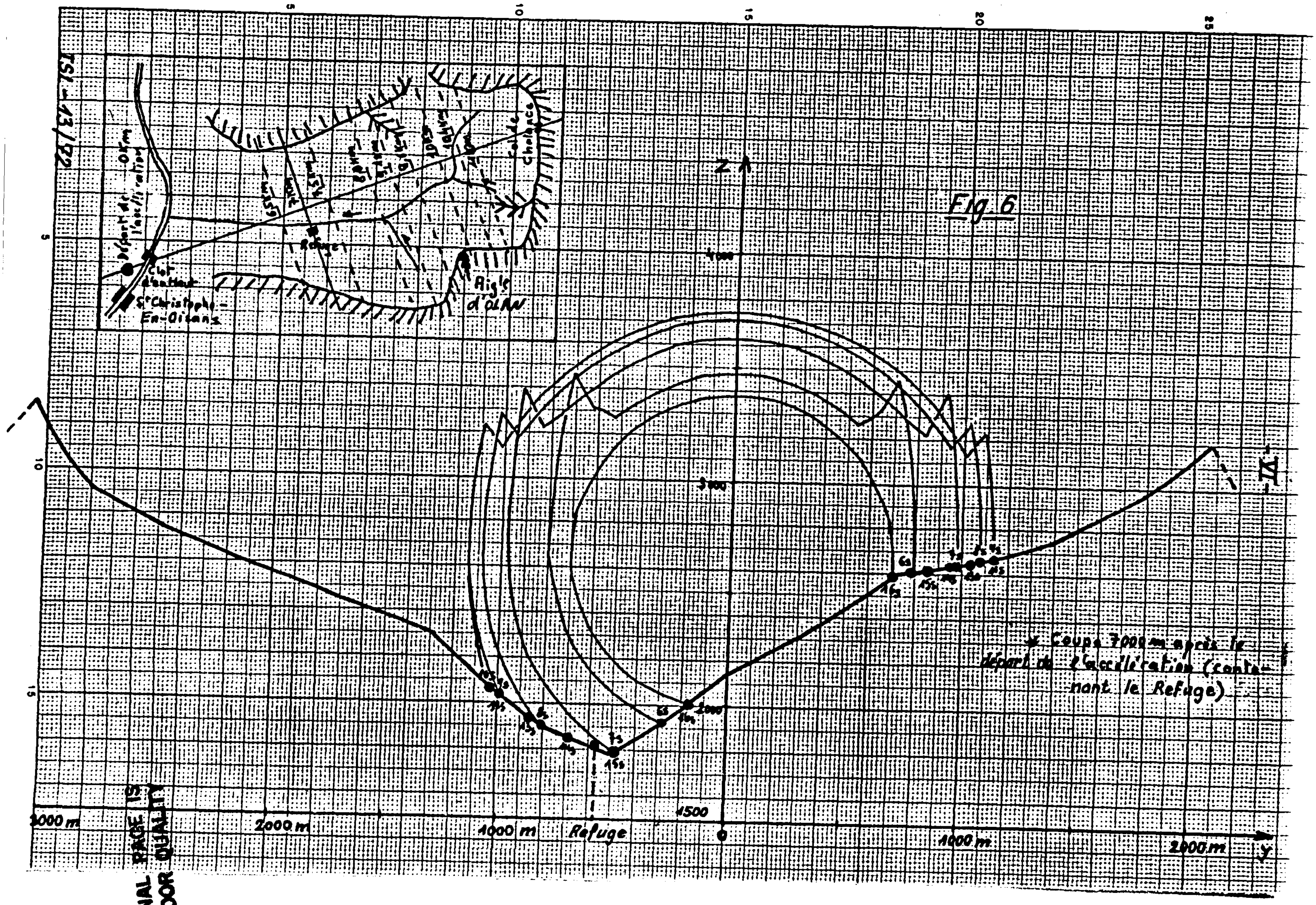
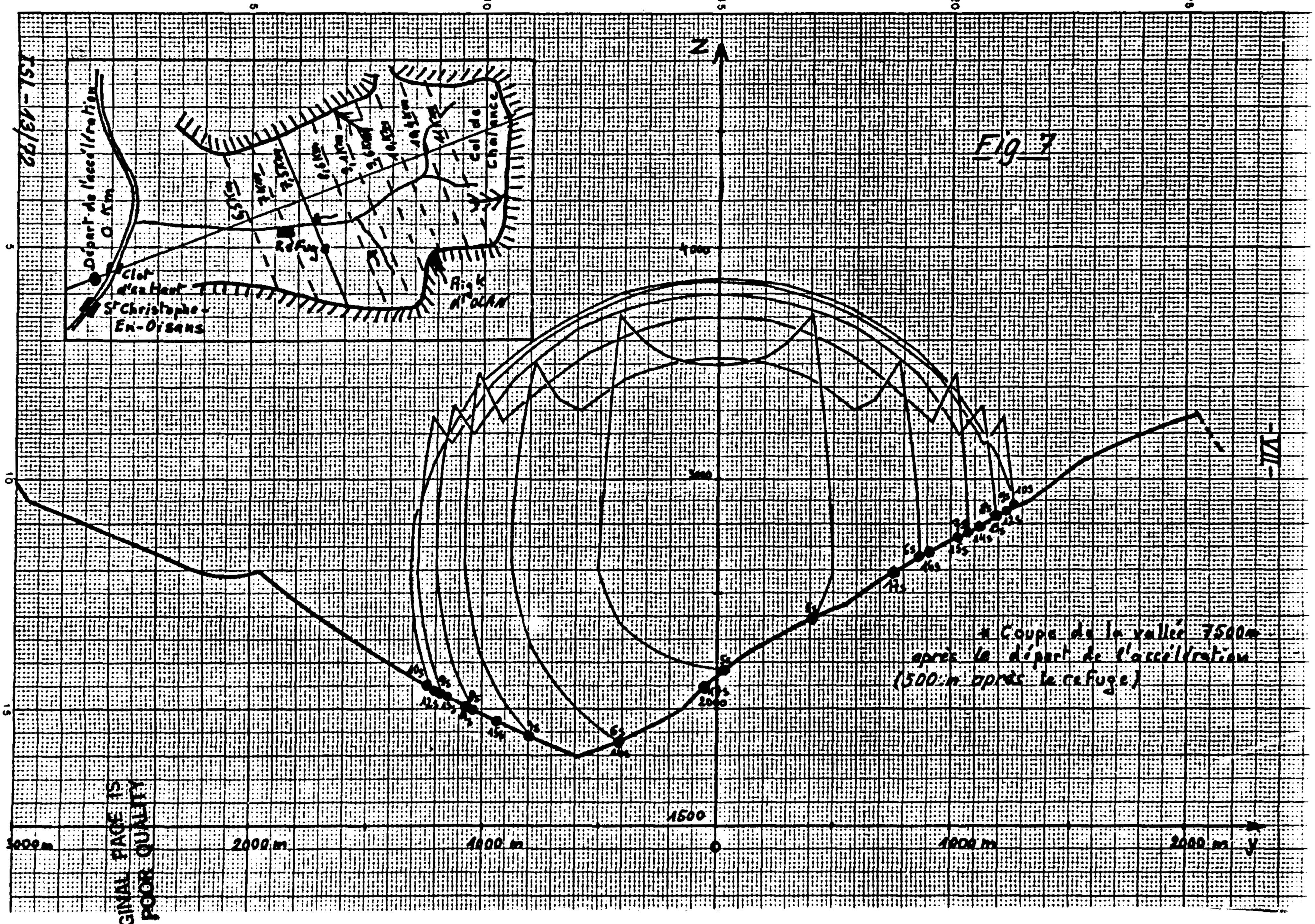

TSI - 13/72
Départ de l'accélération
0 Km
Clot d'en Haut
St Christophe - En-Oisans
Aig le d'OLAN
Col de Cholance
Z
Y
1500
2000
3000
4000
2000 m
1000 m
Refuge
0
1000 m
2000 m
* Coupe 7000 m après le départ de l'accélération (contenant le Refuge)

Fig 6


ISI - 13/72
Fig 7
Départ de l'accélération
O Km
Clot
d'en Haut
St Christophe-
En-Oisans
Refuge
Col de
Chalance
Z
Y
1500
2000 m
1000 m
0
* Coupe de la vallée 7500m
après le départ de l'accélération
(500 m après le refuge)

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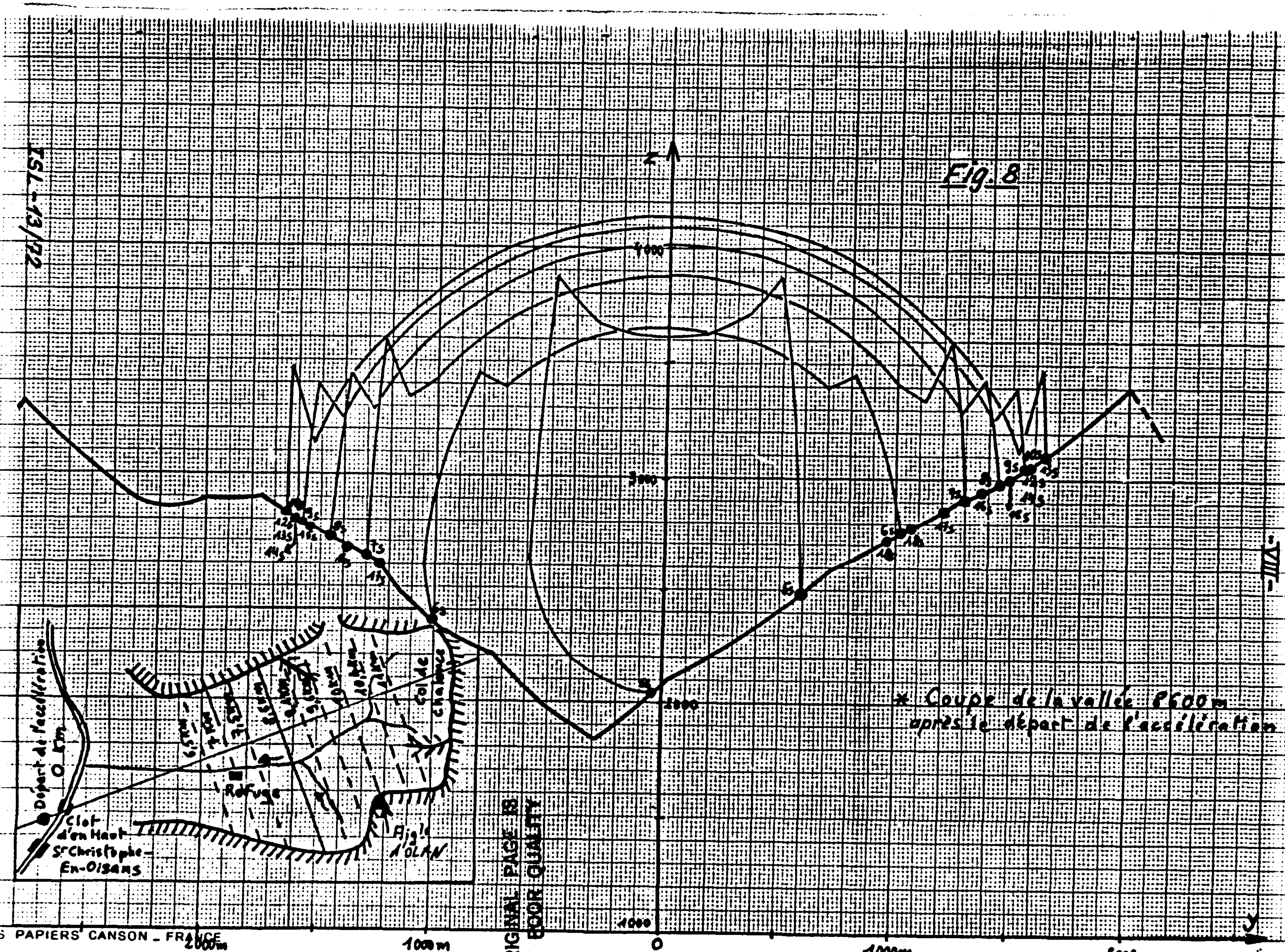

Fig. 8

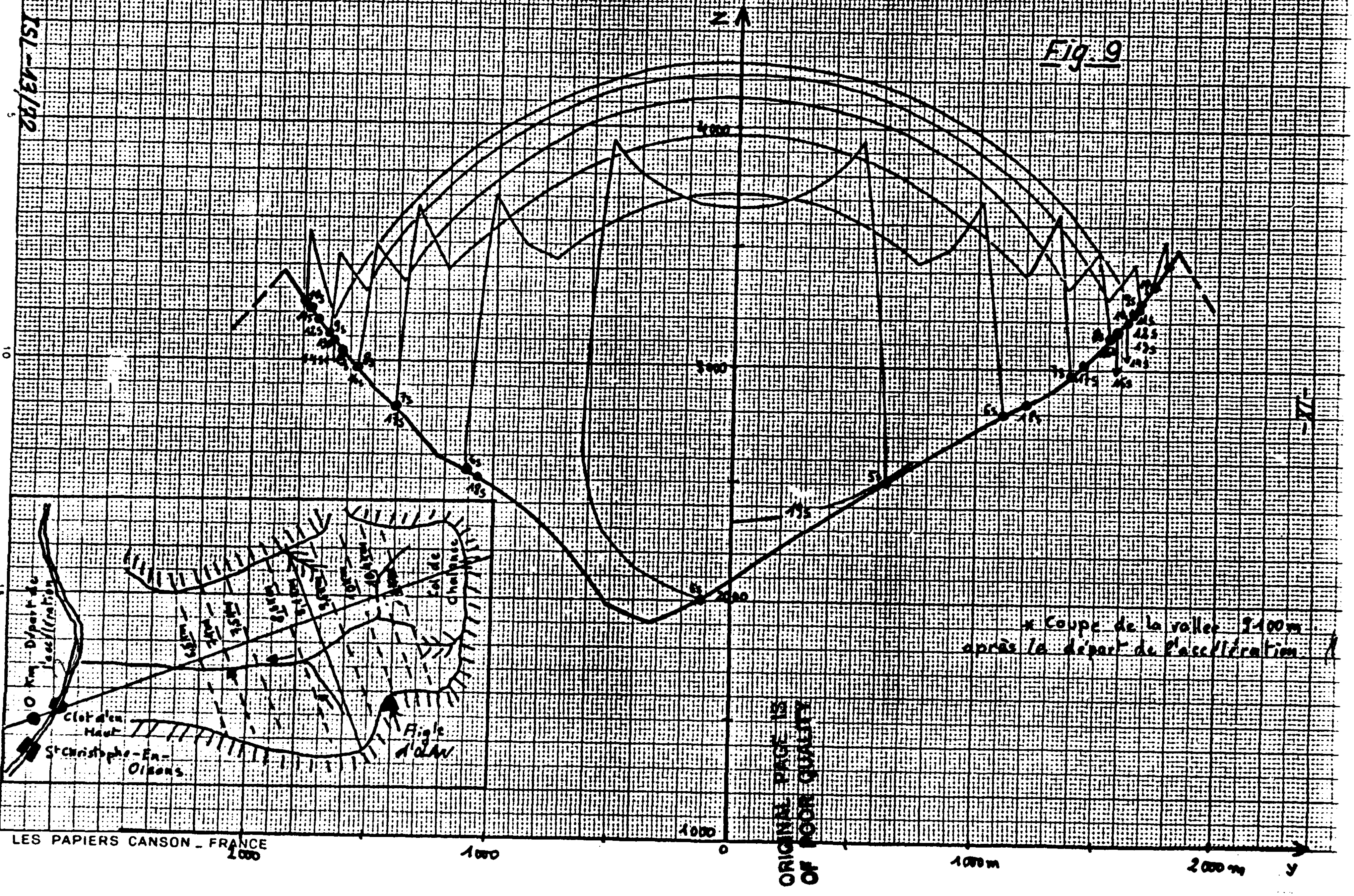
z
4000
3000
2000
1000
0
1000
1000
1000 m
2000 m
y
O Km Départ de l'accélération
Clot d'en Haut
St Christophe-En-Oisans
Aigle d'Olan
Col de Chalance
* Coupe de la vallée 9100 m après le départ de l'accélération

Fig. 9

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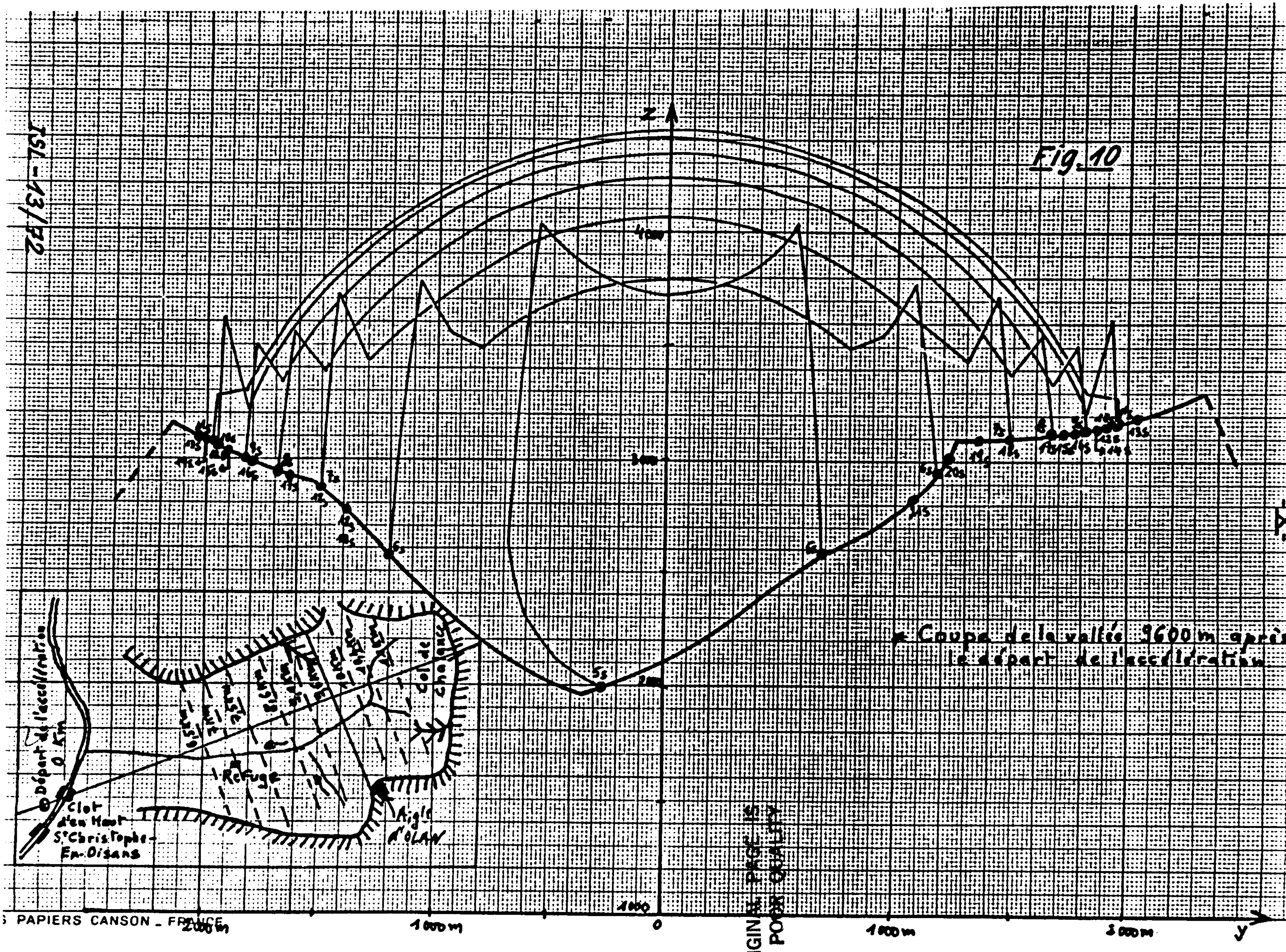
Fig. 10
z
y
X
* Coupe de la vallée 9600 m après le départ de l'accélération
Départ de l'accélération
0 Km
Clot d'en Haut
S^t Christophe-En-Oisans
Refuge
Col de Chalance
Aigle d'OLAN
2000 m
1000 m
0
1000 m
3000 m
PAPIERS CANSON - FRANCE

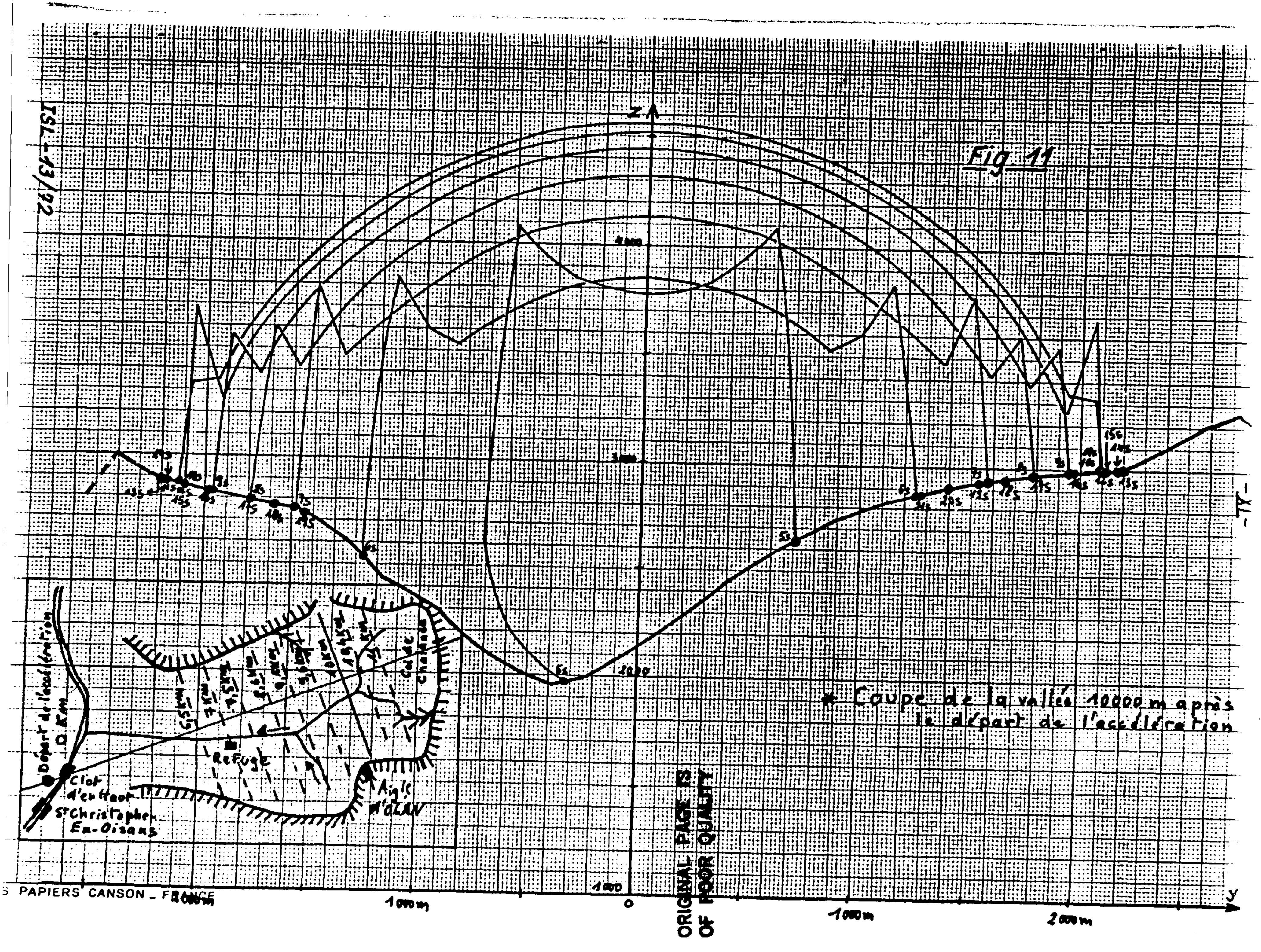
Fig 11
* Coupe de la vallée 10000 m après le départ de l'accélération
Départ de l'accélération
0 Km
Clot d'en Haut
St Christophe-En-Oisans
Refuge
Col de Chalance
Aig. d'OLAN
6,5 Km
7 Km
7,5 Km
8,6 Km
9,6 Km
9,6 Km
10 Km
10,4 Km
11 Km
Z
Y
-TY-
1000 m
0
-1000 m
2000 m
2000
3000
4000
PAPIERS CANSON - FRANCE

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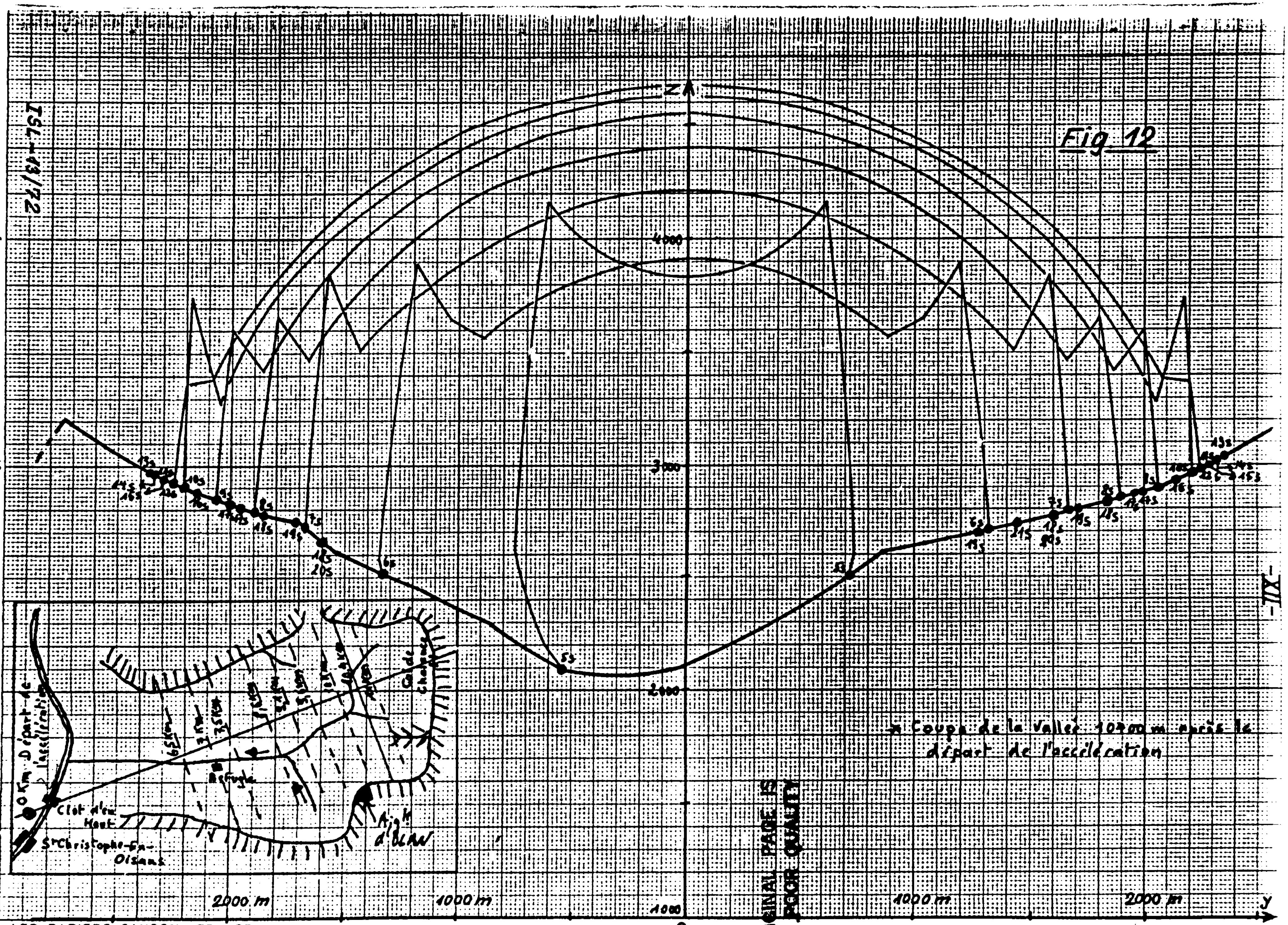

Fig. 12

* Coupe de la Vallée 10400 m après le départ de l'accélération

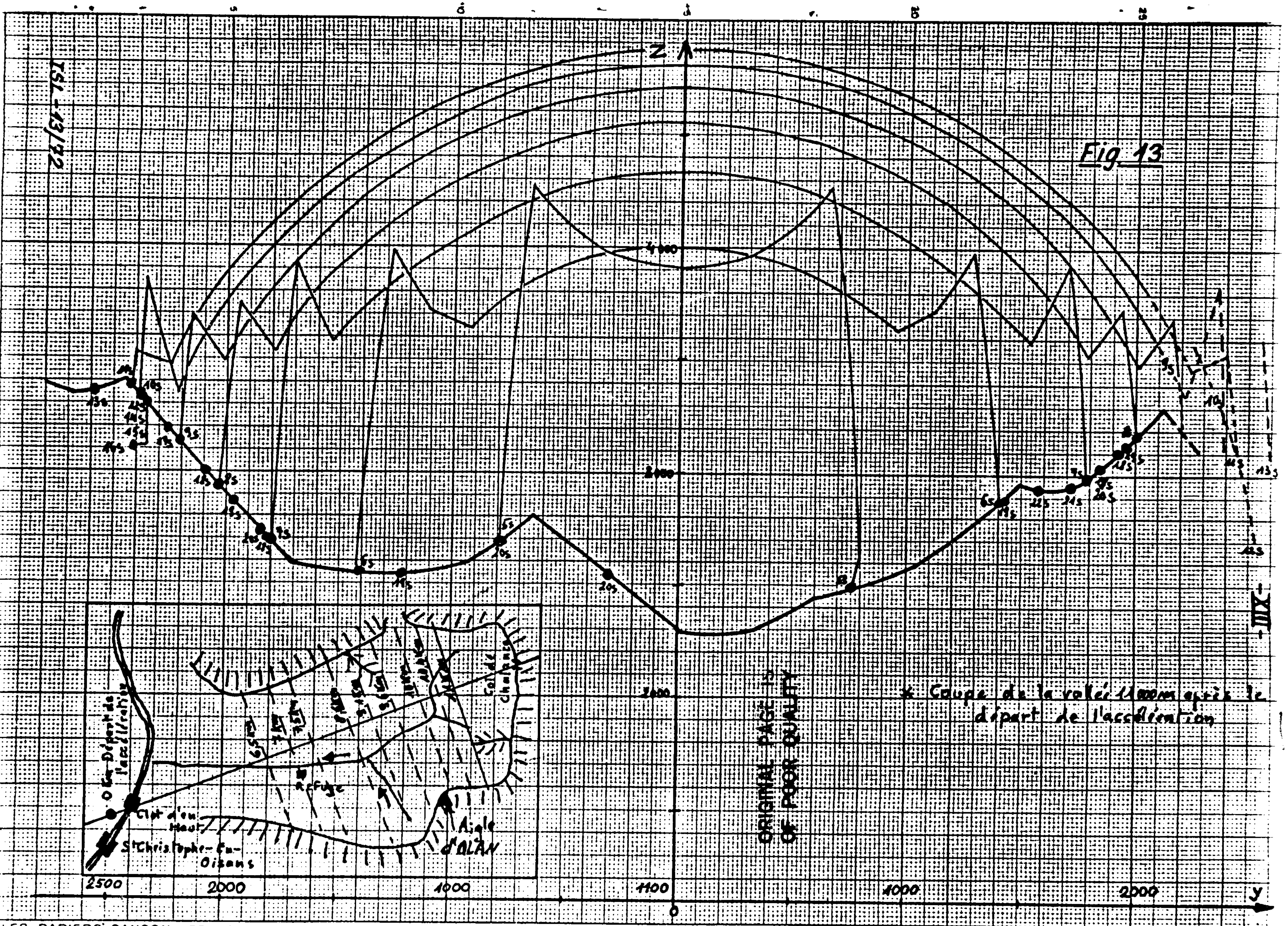
Z
y
4000
2000
1100
0
1000
2000
2500
O Km Départ de l'accélération
Clot d'en Haut
St Christophe-En-Oisans
Refuge
Aigle d'ALAN
Col de Chalance
* Coupe de la vallée 1100 m après le départ de l'accélération

Fig 13

STANDARD TITLE PAGE

1. Report No. NASA TM-88535	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle EFFECT OF SONIC BOOM ON AVALANCHES. PREPERATION FOR FLIGHT OF A SUPERSONIC JET OVER THE LAVAY VALLEY		5. Report Date
		6. Performing Organization Code
7. Author(s) M. Schaffar, B. Carrie, P. Amardeil		8. Performing Organization Report No.
		10. Work Unit No.
9. Performing Organization Name and Address Leo Kanner Associates 1800 Broadway Suite 3 Redwood City, CA 94063		11. Contract or Grant No. NASw-4005
		13. Type of Report and Period Covered Translation
12. Sponsoring Agency Name and Address		14. Sponsoring Agency Code

15. Supplementary Notes

Institut Franco-Allemand de Recherches, St. Louis (France)
Rept. ISL-13/72. June 6, 1983. 73N21940

16. Abstract

An experiment to determine the effect of sonic booms on the stability of the snow mantle in the Lazay Valley is proposed. It includes provisions for the aircraft trajectory, line of focus, boom zone, as well as the determination of boom intensity levels for the whole valley.

17. Key Words [Selected by Author(s)]	18. Distribution Statement Unclassified-Unlimited

19. Security Classif.(of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of pages 18	22.