# ADAM+EVA, A UNIVERSAL SCANNING AND MEASURING MACHINE FOR FILM FROM THE LARGE BUBBLE CHAMBERS

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## 1. Introduction

ADAM+EVA is a universal scanning and measuring machine for film from the large European bubble chambers. It is essentially a highly automated, manually operated film-plane digitizer, particular attention having been given to scanning facilities. Universal should be interpreted as meaning easily adaptable to film from BEBC, Gargamelle and Mirabelle.

When the ADAM+EVA design was started, the aim was to have scanning and accurate measuring equipment operational by the time the first film would become available. Taking account of the uncertainties existing at that time as to film quality and contrast, a classical film-plane digitizer, operating on-line to a computer offered the safest approach.

On the other hand we expected the scanning to be more difficult than for conventional chambers. Some aids in scanning were therefore thought to be necessary and in our opinion these could best be provided by an on-line computer communicating with the operator. If this principle is accepted a one-pass analysis scheme is feasible and has several further advantages : filmhandling is reduced to a minimum and transfer of scanning information is no longer needed.

We therefore combined our original designs [1] for separate scanning and measuring apparatus into a design for one machine. This was easy to do and added very little to the cost of the original scanning machine. ADAM+EVA is thus one of the first machines specially designed for a one-pass treatment of bubble chamber film with the

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availability of real assistance by computer, both in scanning and in measuring.

The high degree of automation and the excellent performance in speed of operation has been obtained by having all controls for each single machine in a 4K PDP8/L computer. A number of ADAM+EVA's can then be connected via the PDP8/L's to an on-line computer, which in our case is a CDC 3200. The fact that the ADAM+EVA hardware is indirectly controlled by the 3200 computer has given us the possibility of providing active help to the operator in scanning and measuring.

Figure 1 is an outline of the configuration of the ADAM+EVA system, indicating the tasks assigned to the various components. A sufficiently large on-line computer is essential if powerful tests (e.g. spatial reconstruction) on the measured data are required, but the device could be operated under control of the PDP8/L alone if desired.

The following paragraphs will bring out in more detail some of the features of the ADAM+EVA system.

## 2. Projector

Figure 2 shows, at the left hand side and centre how the apparatus is being installed : the different views of a single frame are projected down onto a table located one floor below.

However, if one has no objections against using large mirrors (1.4 x 2.3 $m^2$) the projector can be turned upside down and the table placed alongside it (see Fig. 2, right-hand side). The film-gates are fixed and the lenses (Schneider D-Claron 210 mm, f/5.6), mounted on a precision X-Y-stage, can be displaced by an amount sufficiently large (180 mm in X, 70 mm in Y) to move the images over the whole area of the scan-table (2.50 x 1.20 $m^2$). The operator is seated at a short end of the table. For Gargamelle and Mirabelle film the projections of different views overlap by a predetermined amount in order that the beam-plane of these chambers is correctly reproduced in the projection. A reference reticle, which is rotatable, is projected onto the table at a convenient distance from the operator. Measurements are made in the usual way by centering a point on the reticle and reading out the "scalers" (see below) associated with the encoders of the stage movement which have a 2 μm least count. The angle of rotation of the reticle is also digitized with 512 least counts per radian to a very good approximation. Stage movements over short distances are controlled by a track ball; fast movements over longer distances can be initiated by push-buttons. Each button corresponds to a zone on the frame and pressing it moves the stage to a position where the selected zone is centered around the reference reticle. This movement takes generally less than 1 second.

The lamp housings have to follow the stage movement and in order to eliminate static and dynamic loads on the measuring stage, a separate servo is used. The coordination is achieved in the PDP8/L.

The magnification from film to table is 17X, but it is our intention to display the region around the reference reticle on a TV-monitor with a variable magnification of 17 to 50 times. A TV-camera simply looks at the optical projection on the table. We are currently comparing different cameras (vidicon and plumbicon) and making further tests to obtain the best quality of the display.

The filmtransports, which are easily accessible, are very simple. The filmposition is digitized to 0.2 mm using the perforation holes. A step by step control is the main feature, the advance of one frame (380 mm of Gargamelle film, 313.5 mm for Mirabelle) being performed in 1.3 seconds. The rewinding speed will be limited to 3 m/s.

The photographs of Figure 3 and 4 shows a projector in the course of assembly, with the doors carrying the filmtransports closed and opened respectively.

## 3. Control by PDP8/L

The tasks of the PDP8/L are multiple. It counts all digitizer pulses, it is the basis of all servo controls (stage, lamp-housings, reticle, filmtransports), it handles all communication with the operator and the 3200, and it reacts to the controls on the console and to alarms. All controls are entirely digital, which reduces considerably the electronics, and which allows us to elegantly merge and interlock commands coming from different sources : operator, on-line computer or PDP8/L itself.

### 3.1 Counting of Digitizer Pulses

The memory increment facility, which is available on the PDP8/L is used for counting digitizer pulses. Two different memory addresses are used for each encoder : in the first location forward pulses are counted, in the second all backward ones. Two more locations are required to deal with overflow conditions.

The machine contains a large number of encoders : for stage, lamp-housings, filmtransports, reticle, trackball and the reticle control, a total of 2 linear and 10 rotary encoders. Obviously one should never lose a single digitizer pulse. To cope with cases where two or more pulses arrive within the duration of the longest instruction cycle of the PDP8/L (4.8 $\mu$s) the memory increment requests have to be stacked together with the address associated to each of them. If a request causes an overflow, it is re-entered in the stack, with a modified address.

### 3.2 Direct Digital Control of X-stage

The principle of the digitally controlled servos will be outlined using the X-stage servo as an example. Figure 5 is a schematic of this servo. An external clock interrupts the PDP8/L program every two milliseconds. By simple arithmetic operations on the contents of the locations where the digitizer pulses are counted, the instantaneous position $X_a$ of the stage is obtained. Comparison with the desired position $X_s$ results in a value for the error E. The time derivative of the error, $\dot{E}$, is approximated by subtracting the value of E at the previous clock interrupt. A control function $F_u = E + K\dot{E}$ is calculated where K is a constant related to the damping [2]. $F_u$ is quantized to a limited number of values (8 pos. and 8 neg.) with the help of a staircase function (see inset of Fig. 5). The quantized value is then output to a register. A resistor summing network, an operational amplifier and a power amplifier produce the voltage applied to the printed circuit motor which drives the stage via recirculating ball-screws.

Figure 6 gives an idea of the performance obtained in this way from a model of the stage, which has a mass of 20 kg*. The curves, which show the acceleration and the decelaration phases of the movement are drawn from the output of the PDP8/L obtained during the tests. The total displacement was 171 mm in this test. The top speed of 170 mm/s was obtained to within 10% in 60 ms. The final position was crossed for the first time after 1.02 s. After 1.15 s the overshoots are smaller than 15 μm, and it takes not more than a further 0.2 s for vibrations to die out and for the servo to stay at the desired position to ± 2 μm. We have reason to expect that these preliminary results can be improved by adjusting program parameters.

### 3.3 Other Controls and General Organisation of PDP8/L Program

The various other servos are controlled in essentially the same way. The PDP8/L program looks after each of them by entering, after a clock interrupt, all active servo routines in succession. Each servo routine has the task to make and to maintain "$X_a$" (the actual position) equal to "$X_s$" (the desired position). When under trackball control, $X_s$ is calculated from the memory increment locations associated with the trackball. But $X_s$ can also be set directly by the program, and in this way commands received from the 3200, or from the operator via the zone buttons, are executed.

Depressing a console button in general results in an interrupt to the PDP8/L. The program, examining a number of status words, determines the exact source of the interrupt and enters the associated routine. The tasks of the interrupt routines are generally very simple. Often they consist of setting the contents of a given location to some value.

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* The mass of the ADAM+EVA stage will be 40 kg, but the other parameters of the servo are such that this should make practically no difference.

For communication with the 3200 computer the operator has a keyboard and a teletype at his disposal. Messages return from the 3200 on display lights or on the teletype, depending on their complexity, but more often than not, the 3200 or the PDP8/L would exert a direct action on the ADAM+EVA hardware.

## 3.4 Interface PDP8/L - 3200

The interface 3200 - PDP8/L allows a number of possibilities : besides the transfer of blocks of data in both directions, loading, overlaying and dumping of PDP8/L programs can be performed. These programs will be kept in absolute code on the disks of the 3200. The data taking is buffered by the PDP8/L. The data blocks transferred can contain either measurements, or characters or requests for certain actions. Header words specify in detail the contents of each block.

For the actual transfers the data break facility of the PDP8/L is again used and interrupts to either computer initiate the required action in the computer concerned. A status register is the kernel of the interface [3].

## 4. Hardware Facilities for Aid in Scanning

Another paper presented to this conference [4] contains a description of a software system to provide aid in scanning and in measuring. In the present description of ADAM+EVA we will therefore not enter into details of our planned software system. Nevertheless we must point out that the ADAM+EVA hardware, due to its high degree of automation, offers a number of possibilities which can be very useful for aid in scanning and measuring :

1) The digitized reticle makes measurement of direction of tangents of tracks possible. When, during scanning, the tangents of all tracks at the vertices of interest are measured this information can be exploited at different other phases of the analysis. It allows a track matching to be performed, it facilitates communication with the operator (by centering and orienting the reticle on the track to which the program wants to draw his attention) and it provides a means of associating $\Lambda$'s, $K^0_S$'s and $\gamma$'s.

2) The stage can be driven along any curve. In particular this curve - taking lens distortions into account - might be the projection of a lightray onto a view. Supposing the lightray originates from a measured point on view 1, the projection of it on view 2 can then be used to find the corresponding point on a track (or a number of candidates on different tracks). The stage is driven slowly along the curve and the operator is asked to stop the stage when it crosses a track. A tangent measurement made at the corresponding point can then further help to disentangle ambiguous situations in trackmatching.

3) When measurements are made on a track by track basis, the facility of positioning the stage and reticle can be used to indicate to the operator the continuation into a third view of a track already measured in two views. For this a 2-view reconstruction of the track must be made which can then be projected onto the third view.

## 5. Conclusion

We hope to have shown that even in a conventional film measuring system based on a mechanical stage movement there is still room for improvement and interesting development. It is our belief that when we succeed in implementing effective automatic fiducial measuring and track following on ADAM+EVA we will have a system which can compete in overall throughput with many automatic measuring systems which require prescanned film. This will be particularly true if scanning turns out to be the bottleneck in the analysis of Gargamelle and Mirabelle pictures. In that case a system of the ADAM+EVA type stands a fair chance of being the most economical solution.

## References :


1. G. Chanel, C. Verkerk, D. Wiskott; Preliminary designs of scan tables and film plane digitizers for the big bubble chambers. Report CERN - DD/DA/68/8.

2. P. Stürzinger; Designing the ADAM+EVA stage control using MIMIC simulation language. Report CERN - DD/DH/70/1.

3. G. Chanel, A. Fucci, C. Mazzari, P. Stürzinger, A.I. Vaghin and C. Verkerk; Hardware development of the ADAM+EVA project. Report CERN - DD/DH/70/4.

4. H. Burmeister, D.C. Cundy, H. Sletten and W. Venus; Scanning and measuring of heavy liquid film on-line. Proceedings of this conference.

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Figure Captions

1. Layout and tasks of the ADAM+EVA system.

2. Installation of projectors for direct projection (left-hand side and centre) and for projection via mirrors (right-hand side).

3. ADAM+EVA in the course of assembly. The projector is arranged for Mirabelle film.

4. Inside of ADAM+EVA.

5. Schematic of X-stage control.

6. Performance of X-stage servo. The table represents output obtained from the PDP8/L during tests. The acceleration and deceleration phases of the movement are plotted at the right-hand side. Note change of scale at t=1120 ms and setting accuracy at $t > 2400_8 = 1280_{10}$ ms (see table).

## ADAM + EVA CONFIGURATION

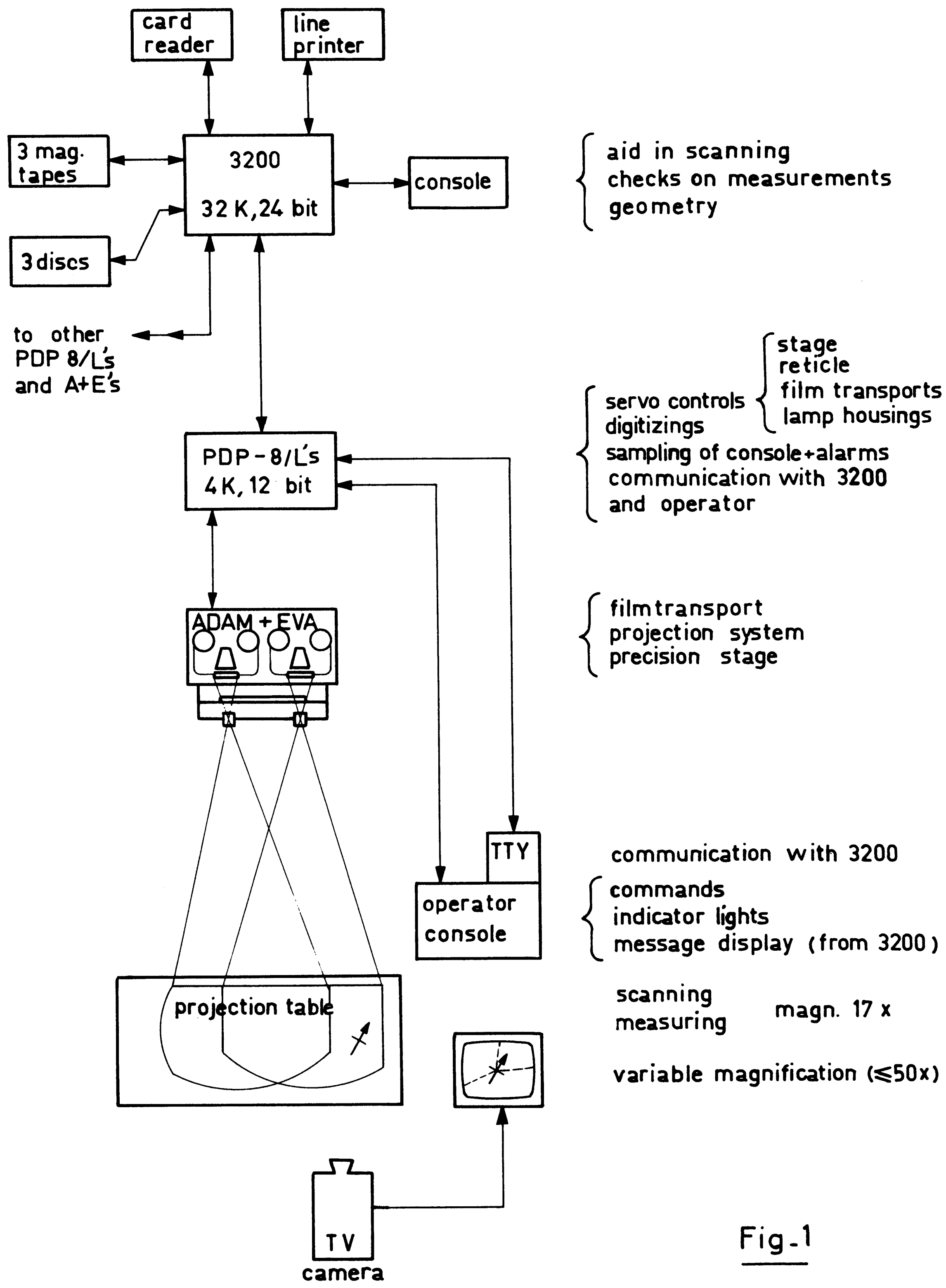
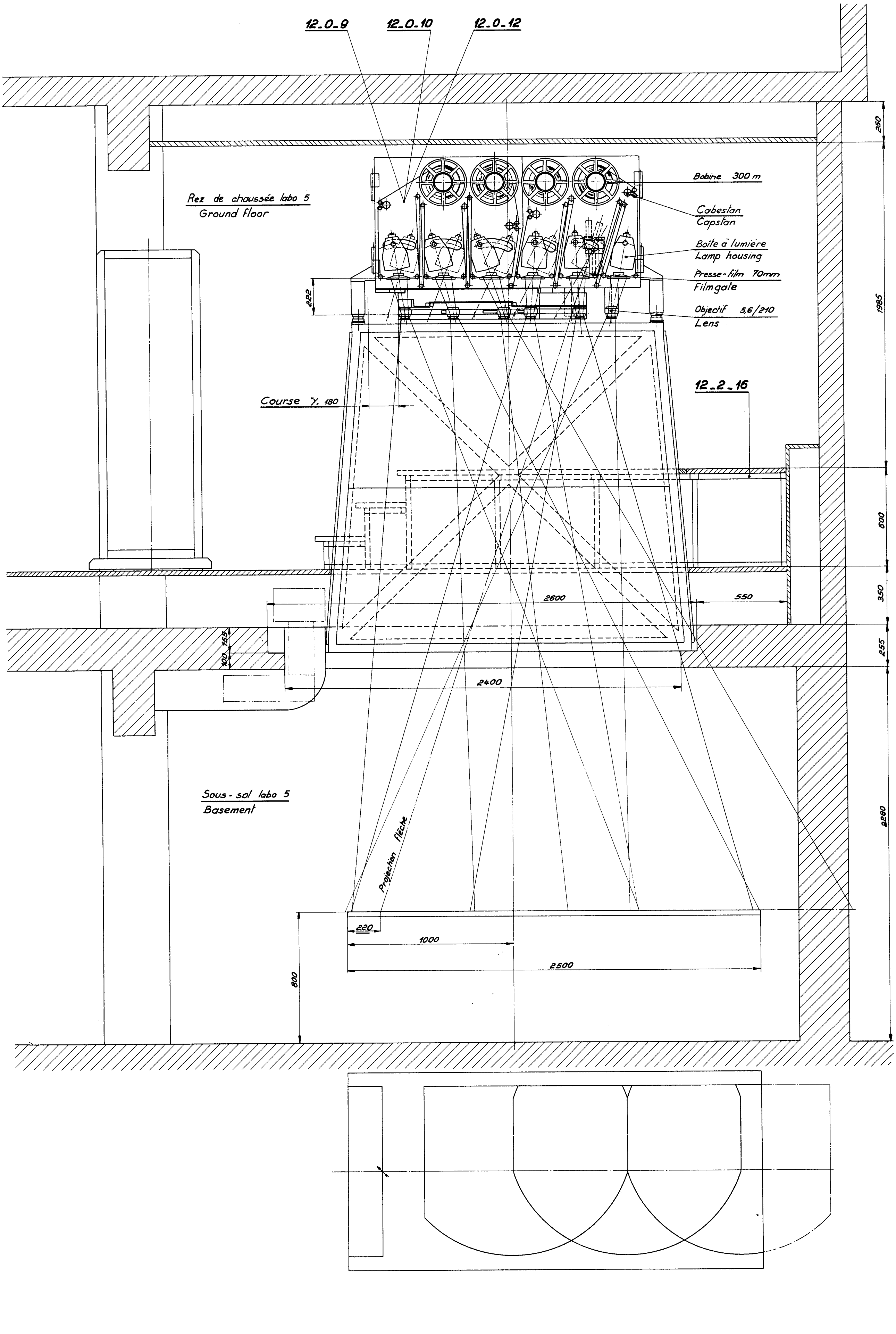
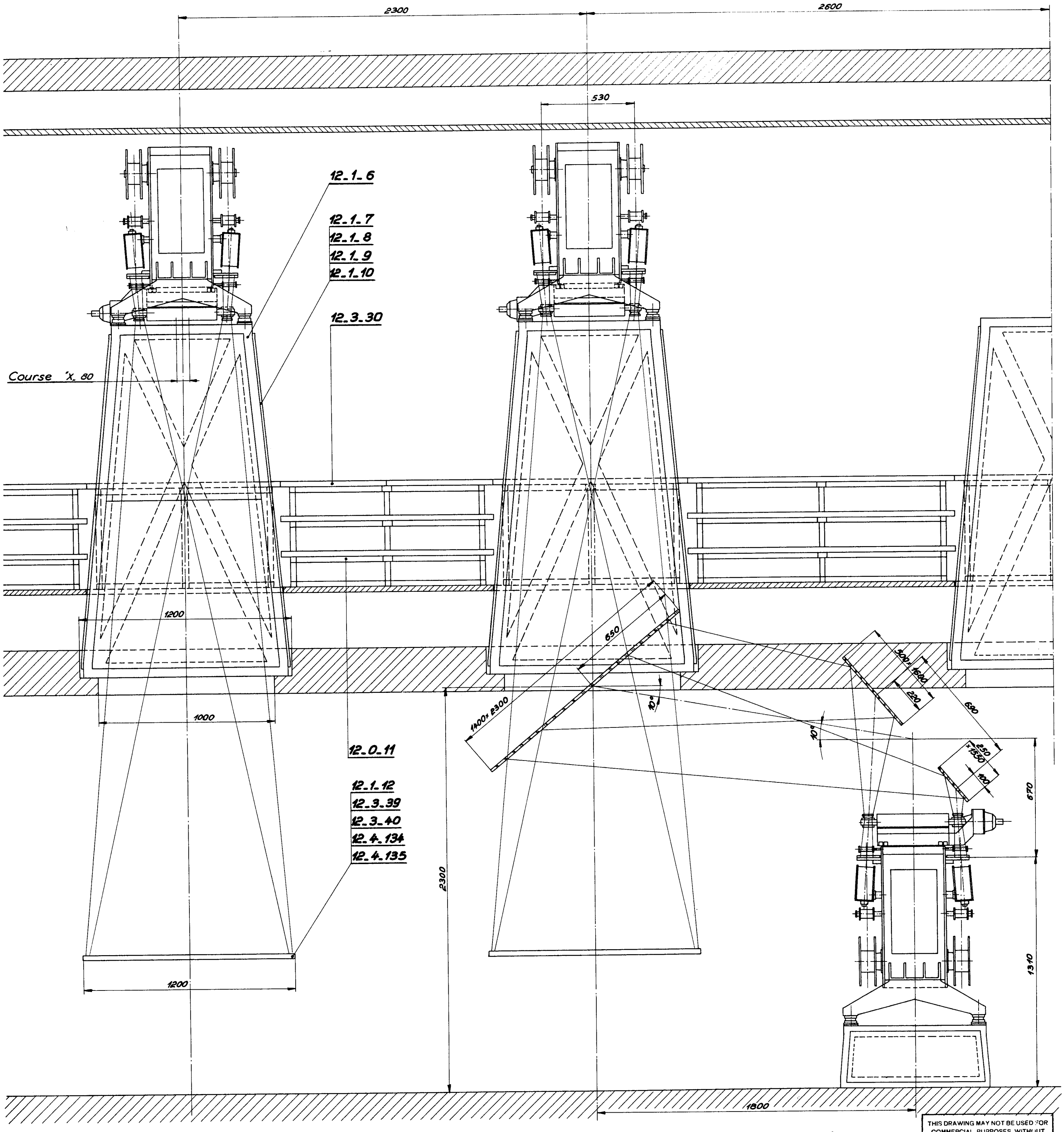



Fig.1


12.0.9
12.0.10
12.0.12
Bobine 300 m
Cabestan
Capstan
Boîte à lumière
Lamp housing
Presse-film 70mm
Filmgale
Objectif 5,6/210
Lens
Rez de chaussée labo 5
Ground floor
222
Course Y. 180
12.2.16
2600
550
2400
100
153
Sous-sol labo 5
Basement
Projection flèche
220
1000
2500
800
250
1985
600
350
255
2280




Projection directe

Projection par miroirs interposés
Projection via mirrors.



Grossissement x 17 - Focale 210 mm
Magnification

Fig. 2

Nb. p. unité / Nb. p. unit — Description — Rep. Item — Matière - Material — Observations
II — I — Rub. — Mod. — Date — Nom — Tolérances générales - General limits — Normes - Standards
A / B / C — de … à … ± / from … to … ± — Abréviations - Abbreviations VSM 10319; Symboles usinage, traitement / Symbols machining, treatment VSM 10320, VSM 10321
Exécution — Ensemble / Assembly — Sous - ensemble / Sub - assembly — Dessiné J. S. 14.10.69 — Contrôlé — Vu
Adam + Eva — Echelle / Scale 1:10
Faisceaux optiques Mirabelle — Remplace — Remplacé par — Réduction
Dossier — ORGANISATION EUROPÉENNE POUR LA RECHERCHE NUCLÉAIRE / EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH / CERN 1211 GENÈVE 23 DIVISION DD — 12_0_14_DD

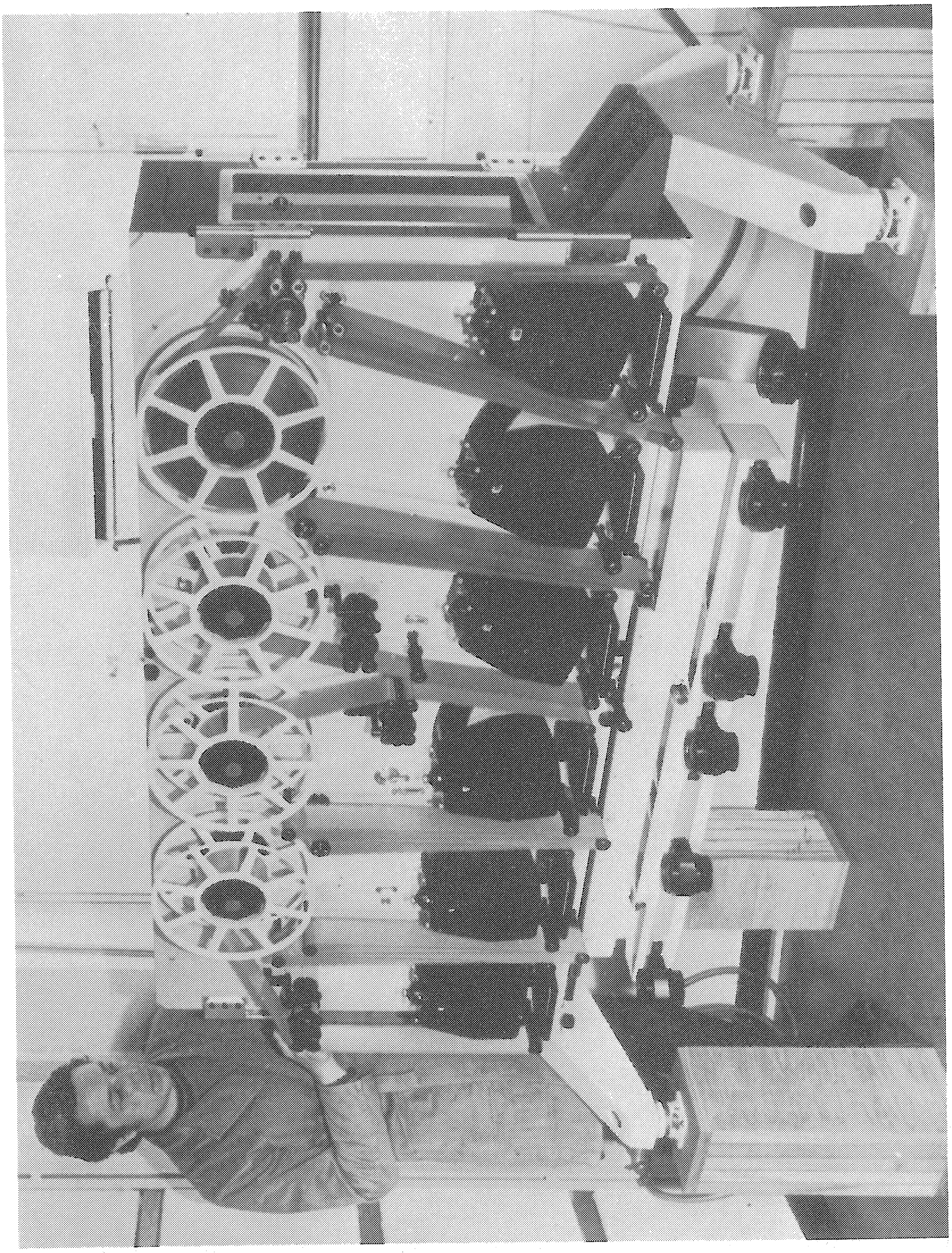


Fig. 3

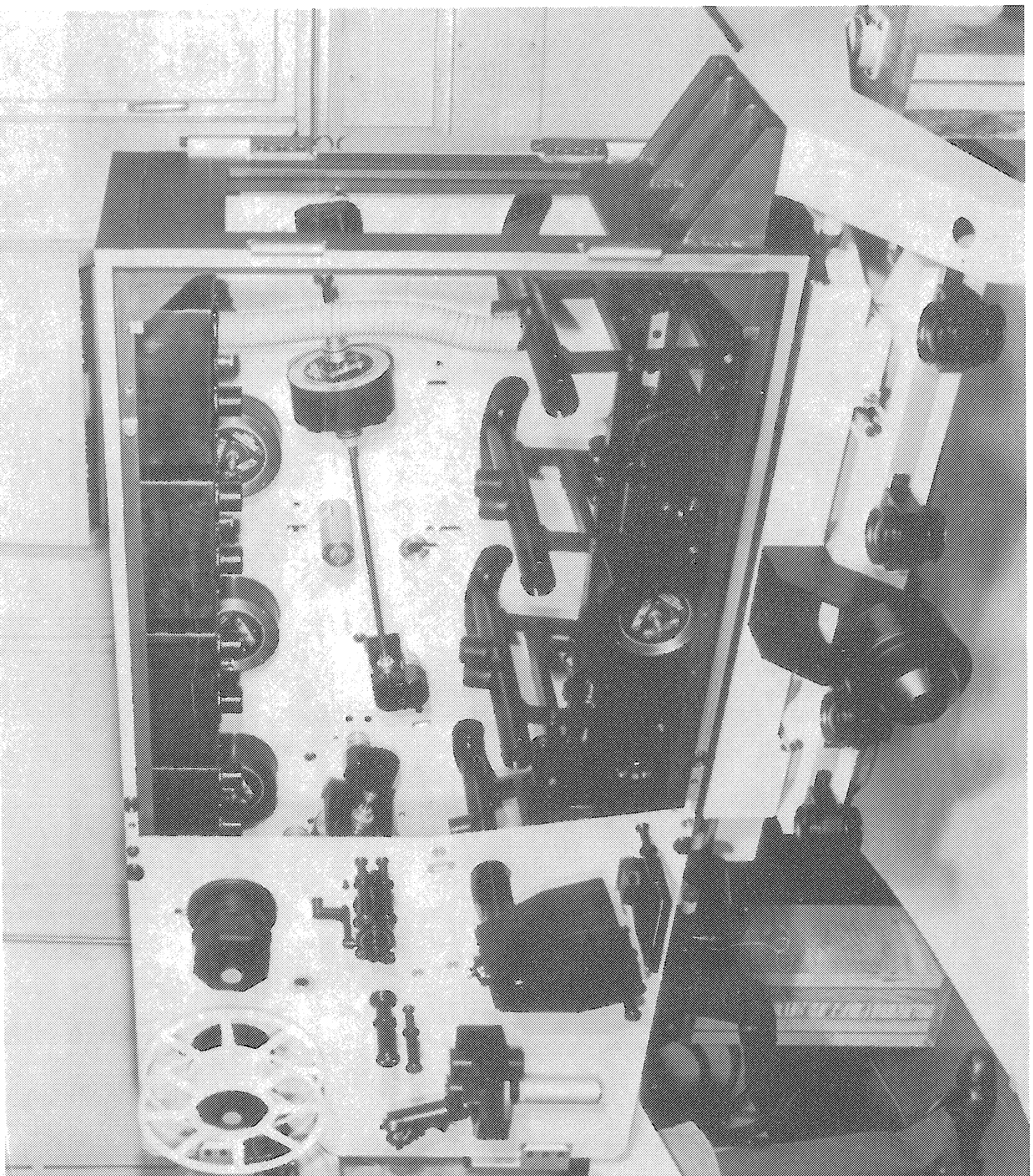


Fig. 4

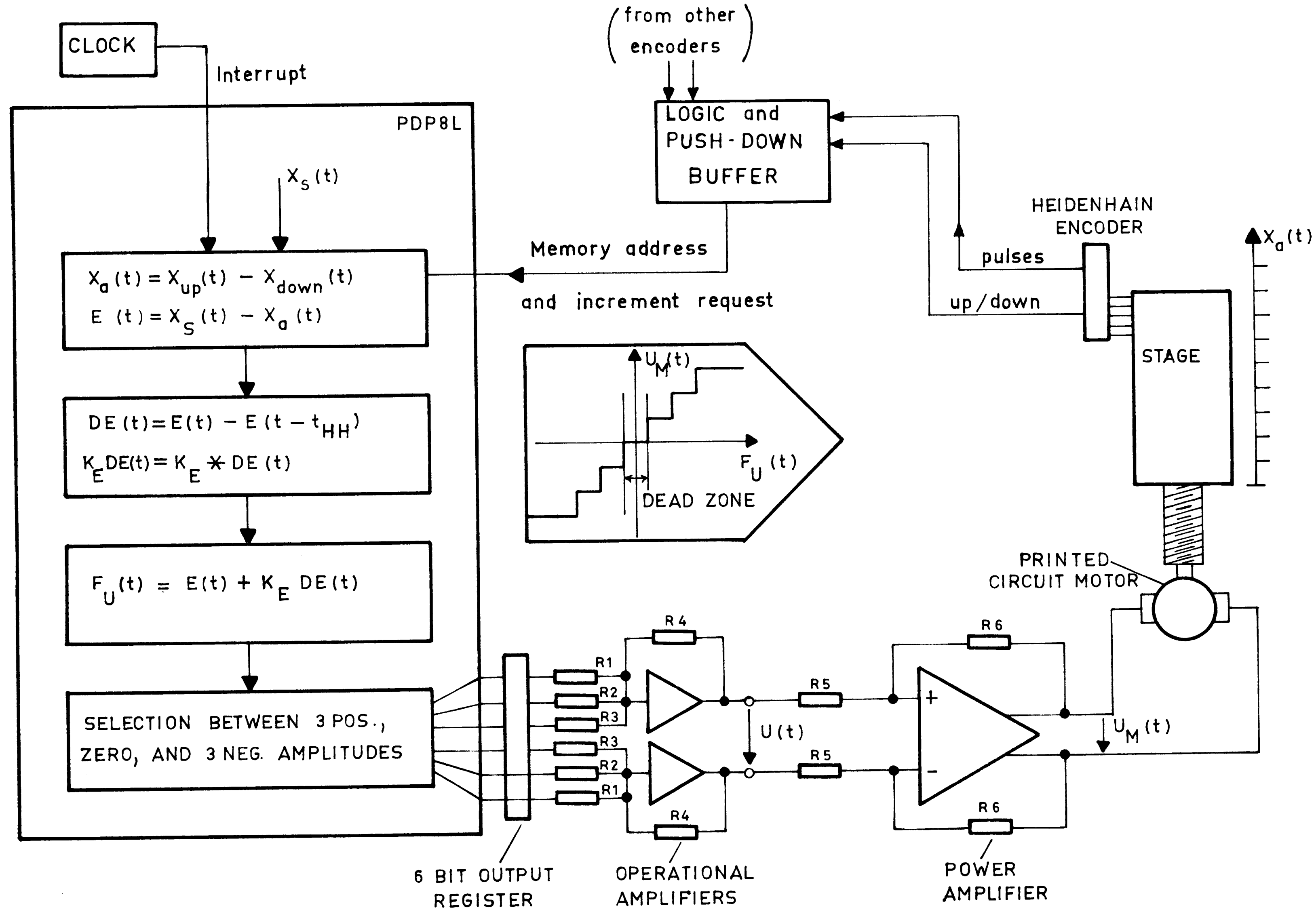

CLOCK
Interrupt
PDP8L
$X_s(t)$
$X_a(t) = X_{up}(t) - X_{down}(t)$
$E(t) = X_S(t) - X_a(t)$
$DE(t) = E(t) - E(t - t_{HH})$
$K_E DE(t) = K_E * DE(t)$
$F_U(t) = E(t) + K_E DE(t)$
SELECTION BETWEEN 3 POS., ZERO, AND 3 NEG. AMPLITUDES
from other encoders
LOGIC and PUSH-DOWN BUFFER
Memory address and increment request
HEIDENHAIN ENCODER
pulses
up/down
STAGE
$X_a(t)$
$U_M(t)$
$F_U(t)$
DEAD ZONE
PRINTED CIRCUIT MOTOR
R1
R2
R3
R4
R5
R6
U(t)
+
-
6 BIT OUTPUT REGISTER
OPERATIONAL AMPLIFIERS
POWER AMPLIFIER

Fig. 5

STEP RESPONSE OF STAGE
MASS 20 KG

1 LEAST COUNT = 2 MICRONS
(ALL NUMBERS ARE OCTAL!)

XA (L.C.) XS (L.C.) AT T = 0
0000 1000 0025 0000

| TIME (MS) | POSITION (LEAST COUNTS | | ERROR (L.C) | SPEED (L.C/ MS) |
|---|---|---|---|---|
| 00 | 0000 | 1124 | 6654 | 0032 |
| 0 20 | 0000 | 1554 | 6224 | 0052 |
| 30 | 0000 | 2346 | 5432 | 0064 |
| 0 | 0000 | 3260 | 4520 | 0076 |
| 0050 | 0000 | 4256 | 3522 | 0103 |
| 0060 | 0000 | 5342 | 2436 | 0111 |
| 0070 | 0000 | 6450 | 1330 | 0112 |
| 0 00 | 0000 | 7623 | 0155 | 0115 |
| 0110 | 0001 | 0776 | 7002 | 0116 |
| 0120 | 0001 | 2205 | 5573 | 0120 |
| 0130 | 0001 | 3420 | 4360 | 0121 |
| 0140 | 0001 | 4653 | 3125 | 0124 |
| 0150 | 0001 | 6105 | 1673 | 0123 |
| | | | | |
| 1740 | 0024 | 5137 | 2641 | 0122 |
| 1750 | 0024 | 6202 | 1576 | 0076 |
| 1760 | 0024 | 7065 | 0713 | 0060 |
| 1770 | 0024 | 7605 | 0173 | 0046 |
| 2000 | 0025 | 0200 | 7600 | 0034 |
| 2010 | 0025 | 0467 | 7311 | 0022 |
| 2020 | 0025 | 0651 | 7127 | 0015 |
| 2030 | 0025 | 0753 | 7025 | 0004 |
| 2040 | 0025 | 0760 | 7020 | 7777 |
| | | | | |
| 2357 | 0024 | 7776 | 0002 | 0000 |
| 2377 | 0025 | 0001 | 7777 | 0000 |
| 2417 | 0025 | 0000 | 0000 | 0000 |
| 2437 | 0025 | 0001 | 7777 | 0001 |
| 2457 | 025 | 0000 | 0000 | 0000 |
| 2477 | 25 | 0000 | 0000 | 0000 |

XA (L.C.) XS (L.C.) AT T=INF.
0025 0000 0025 0000

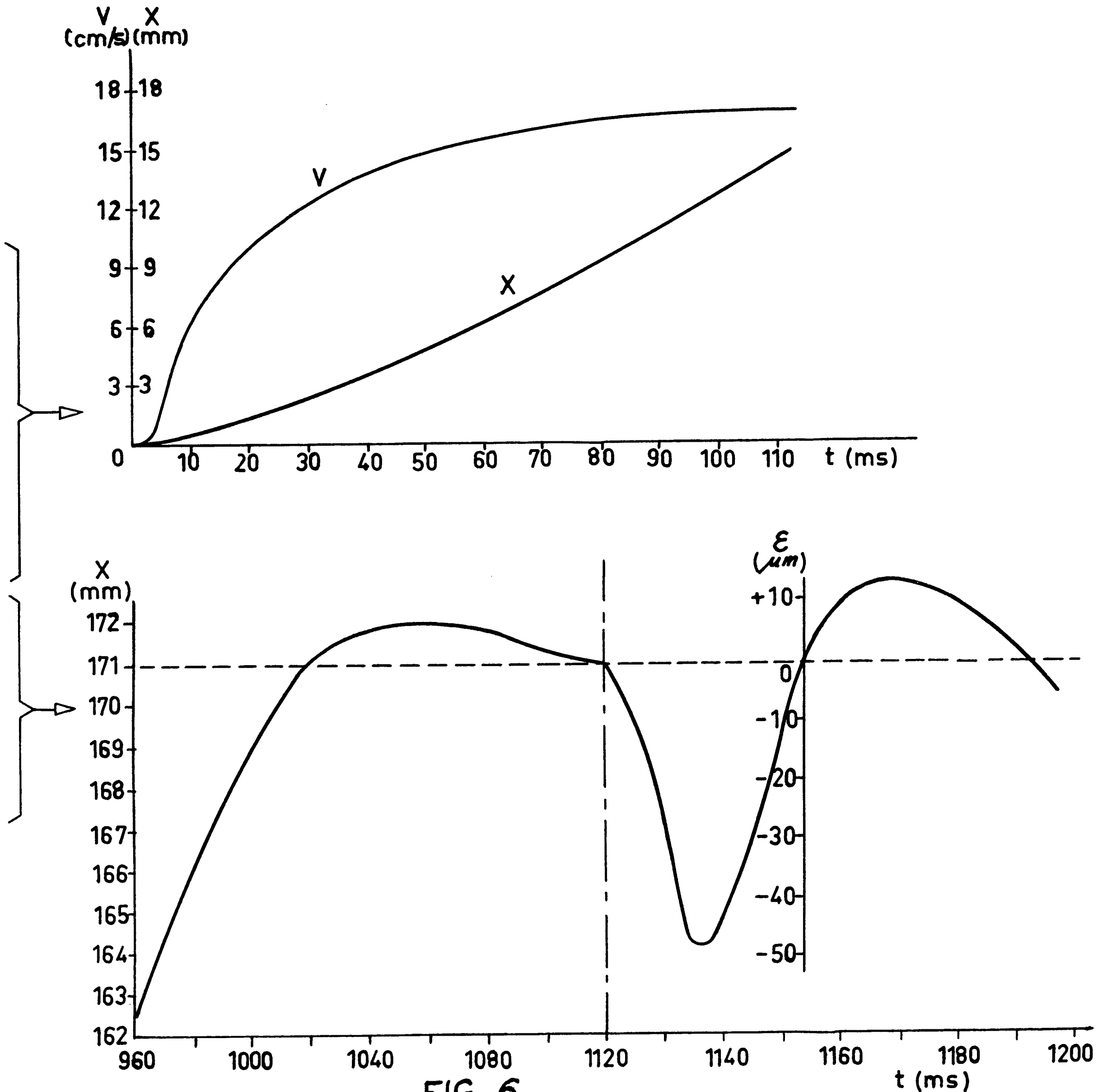



FIG. 6.

## DISCUSSION

O.R. FRISCH *(Cambridge)*: Why is it called ADAM + EVA?

C. VERKERK: This is an acronym of the French Appareil de Dépouillement et Analyse de Mirabelle et EVentuellement Autres chambres.

H. NAGEL *(Bonn)*: Why do you allow an overshoot during stage positioning instead of reducing the speed prior to arriving at the desired position?

C. VERKERK: Figure 6 shows values of a test made before optimization. The behaviour depends on the value of the parameter K (see Fig. 5), the only constraint on this value being that we would like keep it a power of 2 in order to make the calculations simple.

H. SHAYLOR *(Birmingham)*: What is the cost of one ADAM + EVA table?

C. VERKERK: Approximately £30,000 including the PDP-8/L and all workshop labour.

R. BAIRSTOW *(RHEL)*: Could you tell me how much of the PDP-8/L core memory is taken by the servo-control routines?

C. VERKERK: One control routine takes about one page, i.e. 128 locations. Some space has to be added for interrupt routines, etc. We now want to combine all routines for the different servos as far as possible into one loop, taking probably two or three pages.