THE STATUS OF HPD PROGRAMS AT BROOKHAVEN NATIONAL LABORATORY

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(presented by R. Strand)

INTRODUCTION

This paper describes the Brookhaven National Laboratory, Hough-Powell Digitizer system for rapid processing of bubble chamber pictures. The HPD hardware and most of the software have been developed by members of the BNL Bubble Chamber Group. The software runs on the IBM 7094 and CDC 924 computers of the Applied Mathematics Department (AMD). This paper emphasizes software and experience that was gained from the first production running of the system.

The heart of the HPD system is the flying spot digitizer (FSD) which traces a master scan over bubble chamber photographs. Bubble positions, accurate to a few microns are transmitted to the memory of an IBM 7094 computer. With the help of previously rough-digitized three-point roads, the computer is able to locate the tracks within the set of all bubble positions. Average points are obtained which simulate the output of the conventional manual spot digitizers. In addition, bubble density information is obtained for each track. The rest of the analysis, scanning, geometry and kinematics, use the Brookhaven BCG data processing programs.

This paper is organized into seven sections in order of increasing amount of detailed description. Readers with HPD experience should be able to understand the HPD system by referring to the eight figures at the end of the text.

Section I contains a general description of the whole HPD system as it is applied to an experiment. Picture quality requirements, event processing rates and event rejection percentages are reported. In the next three parts of this paper the HPD system is divided into three parts. Each part is discussed in more detail. The road making operation is discussed in Section II, the FSD measurements in Section III, and the kinematics and event selection in Section IV. Section V contains a description of the FSD control program called HAZE. The use of FSD measured bubble density to compute the best event interpretation(s) is presented in Section VI. In Section VII future plans for the HPD system are presented.

I. PRODUCTION EXPERIENCE WITH THE 35 MM HPD SYSTEM

The first large scale experiment to be processed with the HPD system is a study of 3.5 GeV/c $\pi^- + p$ reactions in the BCG 20 inch hydrogen chamber. The picture quality of this chamber is well suited to the elementary track finding methods used in the HAZE program, which controls the FSD. HAZE is able to cope with only a limited number of beam tracks. About twelve tracks per picture were taken. A fast beam pulse was used to provide uniform track age in the chamber. The bubble density was set to about twelve bubbles per centimetre in space. The HPD uses X-shaped fiducial marks on the chamber windows. The bubble chamber arc voltage was adjusted until these fiducial marks had the appearance of stopping proton tracks. The track contrast was brought to a suitable level for the FSD by adjusting the bubble chamber piston stroke or the arc delay. A binary data box is applied to each new photograph. The FSD film transport reads the binary frame number from this data box, and also stops the film with reference to a binary clock track on this data box. It was necessary to monitor the data box quality during the run. Also some of the pictures were tested for overall quality on the FSD.

A block diagram of the current 35 mm HPD system is shown in Fig. 1. The OFFMIF operation has not yet been used for production, and the first production runs have been made without its advantages of saving 7094 main frame time.

In Fig. 1 we see that the film is first scanned and predigitized. Three points are taken on each track in each of the three views to construct 400 micron wide circular roads which guide the HAZE program by eliminating most of the picture from consideration. We refer to this process as maximum guidance.

FILTER, the pattern recognizing subroutine in the HAZE program, attempts to find the correct track within the road. Crossing tracks, close parallel tracks, and noise in the road all contribute to the difficulty of track recognition. It was soon discovered that track failures were too frequent. Only about 80% of the events could be correctly measured with only the computer FILTER. At this time human guidance was brought to bear upon the pattern recognition problem. The rejected road contents were displayed on the IBM 7094 digital CRT. An operator filtered the road by telling the program where the track was located through the use of the IBM 7094 console keys. We called this process manual filter.

Manual filter permitted us to correctly measure 90% of the events. More important though, it helped us find bugs in the system. We were able to measure an average of 80 events per hour with manual filter on-line.

Next the manual filter operation was moved off-line from the IBM 7094 by using a magnetic drum on which to store the rejected roads. Special hardware permits an operator to display the rejected roads on a CRT. The desired co-ordinates can be marked by touching a light pen to the surface of the CRT. This operation is known as "off-line manual filter" or OFFMIF. HAZE is now able to measure an average of 100 events per hour and HAZE plus OFFMIF provide correct measurement of about 95% of the events.

Next in Fig. 1 FOG and CLOUDY perform conventional geometry and kinematics calculations. Finally two versions of the Brookhaven BCG Suffolk County FAIR program are used to select the best fits for each event and to display physical parameters of event collections. The fit selection program is possible because of the ability of the FSD to measure bubble density.

About 10,000 events in 50,000 pictures have been measured with the HPD system. The logistics of this production are presented in Table I. The kinematic analysis is done in two passes through the computer. CLOUDY 208 prepares the lists of mass assignments and CLOUDY 209 constrains the events. Clearly most of the time is spent making the roads. This time could be perhaps cut in half by a "minimum guidance" scheme under which only vector points would be predigitized. It is expected that the next generation computer programs will make this possible. The FSD measuring time, which is most costly, can be reduced by optimizing the HAZE program and improving the FSD film transport and the binary data box on the film. Current stage speeds would limit the maximum attainable production rate to about 200 events per hour.

II. BNL 35 MM HPD SYSTEM PRIOR TO HAZE

We now examine the HPD system in more detail. First before the film is read by the FSD we are concerned with the preparation of the rough digitized roads. A block diagram for this part of the system appears in Fig. 2. We found that the road making operation is more complex than we had expected. In order to improve the road making efficiency we found it necessary to check the quality of the predigitizing with an extra computer program, MISTY. Our goal was to mount the film on the scan table only once and require <u>all</u> the events to be correctly predigitized.

We have used a three-roll unit of about 900 events in about 4,500 total pictures. We prepare checked roads for all of the 900 events before going on to the next three-roll unit. The three-roll unit was selected to optimize both tape storage and the amount of film that can be processed during a four hour run of the FSD. As a redundancy check the scan technician writes down the picture number as well as entering it in the picture number switches. This enables our computing aide to compare a scan list with the events as they are checked by the MISTY program, as shown in Fig. 3. The scanning and predigitizing rate of about 10 events per hour would be approximately doubled if no predigitizing were performed or if the number of measured points were greatly reduced. At present three points on each track and two fiducial marks are predigitized in three views. The set of events which meets the requirements of MISTY and which can be fixed up by the data processing aide is about 95% of the total input. Our data processing aide provides rapid feed back of rejected or missing events to the scan technicians. In most cases these events are predigitized again before the film has been removed from the scan table. As a precaution the last few rejected events are measured twice before the film is removed. In practice we find that the combination of the MISTY program and our data processing aide, effectively trains our scan technicians. They simply improve their techniques until their rejection rates are satisfactory.

We recognized the need to check for format errors in the MISTY program. For example, each event has a format code (i.e. 102 for a two-prong event) that specifies the correct number of tracks for the event. Digitizer errors are also detected by requiring approximately equal point distribution over a moderate turning angle. A standard fiducial mark separation is required of each view. We will add to the MISTY program three more checks. First we will require agreement of the vertex points. Secondly we will make a test stereo reconstruction of each track in order to check track matching errors between views. Thirdly we will reject those events for which two <u>outgoing</u> tracks lie wholly within one road. We have not solved this problem but we have developed a method to handle the case of two beam tracks in the same road. We select arbitrarily one of the tracks. Tests showed that this method has no effect on our measurement of the beam track because of our editing method for beam tracks. After the three-roll unit has passed the checks in MISTY it is used to update the list of events for the experiment which is kept on a bookkeeping tape. The data also is passed through the MIST program which separates it by view and writes it onto three scan tapes for use in the HAZE program. MIST requires the events to be in order and it prepares useful summary listings for each run. MIST also accepts a table of instructions for the mass assignments for each event topology. Mass assignments for kinematic analysis are generated for all events from this table.

At this point in the analysis the three rolls of film are taken from the scanning lab. to the FSD lab. and the three scan tapes are stored in a rack ready for FSD production.

III. BNL 35 MM HPD SYSTEM FROM THE FSD THROUGH GEOMETRY

The HAZE program controls the 35 mm FSD as shown in Fig. 3. We will return to the HAZE program in more detail in section V. For the moment we should note that HAZE produces film geometry points and film bubble density measurements for about 90% of the track views that were predigitized. If the track is short, close to another track, or in general complicated with other tracks or with noise it may not be found by HAZE. In this case all of the points within the road are saved for human inspection as was mentioned in section II. A failed road's contents are displayed on a CRT. With a light pen, a technician can mark those co-ordinates which belong to the track. This operation is under control of the program OFFMIF which stands for off-line manual filter, as shown in Fig. 3. The associated magnetic drum is connected to one data channel of the BNL 7094 computer. The OFFMIF program is called into operation by the technician's pushing an interrupt button for the data channel. At the end of the next Brookhaven AMD monitor job OFFMIF is loaded into the 7094 memory and control is passed to it. If the drum is empty OFFMIF fills it with 32 failed-roads' contents and returns to the monitor system. The technician is able to look at the roads in order and fix or reject each track with the light pen. When the 32 tracks have been examined, the interrupt button is again pushed. OFFMIF is called into core and it reads the 32 corrected roads from the drum and loads the next 32 failed-roads. The corrected roads are merged into the normal HAZE output record. This operation takes about half an hour per drum load.

The drum CRT performs two functions of great importance. In the first place it permits us to achieve a production system before the pattern recognition problems of maximum guidance are satisfactorily solved. Secondly, it tells us how to solve our difficult pattern recognition problems in the HAZE program and it enables us to monitor the effect of HAZE program changes.

HAZE and OFFMIF run with one view at a time. When the three views of our unit of three rolls of film have been measured the measurement quality is checked by a test geometry reconstruction. After OFFMIF about 5% of the events fail to be reconstructed because a track was not properly measured in one essential view. To recover these events, a measuring technician measures the required track in its view along with necessary fiducial marks. These data are merged with the main FSD track data record in the program MTR which stands for multiple track re-run. More than one track-view can be measured and so merged. This program runs on the Brookhaven AMD CDC 924 computer. Four hours of FSD production produces enough work for one manual digitizer shift. OFFMIF or MTR may one or both be omitted after HAZE since all three output formats are identical. We have adopted these methods in order to have 100% event transmission without passing the film through the FSD a second time.

The final FOG run for geometry information terminates the measurement phase of the system. At this time a calculation of the cosine of the angle between the flying spot velocity vector and the track direction is performed in each view. These data are stored in the FOG output records. Each track's bubble density must be corrected by this factor. Since bubble density measurements are in an experimental stage, the raw data along with these cosines are preserved for later study in the Suffolk County FAIR program. More details of the bubble density methods will be presented later in section VI. The output from the FOG runs is merged into one logical FOG library for input to the kinematic analysis programs.

IV. BNL 35 MM HPD SYSTEM FROM KINEMATICS THROUGH ANALYSIS

The CLOUDY kinematic analysis is performed upon a FOG library which may include any number of events in numerical order. The CLOUDY output library contains the kinematic analysis for each desired mass set as shown in Fig. 4. In our experiment frequently the kinematic analysis favours two or more of the mass sets for each event. A typical example is the substitution of a positive pion for a real proton track followed by a successful kinematic fit with a missing neutron. Indeed all bubble chamber experimentalists have at one time or another resolved mass assignment ambiguities by looking at track bubble density on a scan table. We have written a fit selection program which uses the FSD bubble density information and computes the resolution of ambiguities as a physicist might by looking at the scan table. The fit selection version of the Suffolk County FAIR program has been rather controversial, but we have attempted to select the fits step by step as a physicist would select them. FSD bubble density measurements are compared with the measured track momenta and their masses in the usual way in order to be able to select the best mass assignments for an event. The mass fits are then deployed onto their respective tapes as shown in Fig. 5. The bubble density methods are discussed further in section VI. Suffolk County FAIR is used to produce histograms and other plots of the data for a particular reaction. For each requested distribution three plots are prepared based upon the unambiguous sample, the ambiguous sample and the total weighted sample.

V. MAXIMUM GUIDANCE OF THE FSD WITH HAZE

A block diagram of the major features of the HAZE program is shown in Fig. 5. We will outline the HAZE program here. Readers who are not interested in the details of HAZE will be able to skip the next three subsections which will describe our HAZE program in more detail.

At the start of HAZE in Fig. 6, the road information is read from the scan tape. Next HAZE asks the FSD for the frame number which was read from the scan tape and for a scan of the picture. HAZE then waits for the FSD to fill the first 2000 word buffer. While waiting, a routine tests the format of the FSD data and keeps records of mistakes or prints a message when the data becomes impossible.

When the first 2000 word buffer is full, HAZE begins real time competition with the FSD to process one 2000 word buffer before the other is filled. During this real time period the road fiducials and glass fiducials are found as they occur in the 2000 word buffers. Also in real time the subroutine GATE fills the roads with 20 points and then calls on FILTER to histogram the points and finds the tracks. When the 2000 word buffer is exhausted HAZE returns to the pause loop and the FSD data format test.

At the end of the scan the GATE plus FILTER combination handles the last part of the picture. Then HAZE checks the results of the scan. The so-called servo-subroutines adjust the road laying parameters so that the tracks are centred within their roads on the average. The tracks for this event are checked for bad master points or intolerably long gaps. Rejected tracks are flagged and their road contents saved for visual inspection and manual pattern recognition as was already discussed. If an orthogonal scan is required HAZE asks the FSD for an orthogonal scan. Tracks which make 45 degree angles or greater with the long axis require an orthogonal scan. Otherwise the event is written as one record on the output tape and control returns for the next picture.

1. Pre-Real Time HAZE

In more detail we consider that part of HAZE before real time as shown in Fig. 6. In this part of the paper we assume that our readers are program experts so that the Fig. 6 will tend to speak for itself. On the average HAZE seems to spend about 40% of its real time in the pause loop waiting for a 2000 word buffer to be filled. The rest of the total real time is divided approximately into 50% for GATE and 10% in FILTER.

2. Real Time HAZE

In Fig. 7 the real time part of HAZE shows two reasons for halting a scan and asking for a re-scan. If the program failed to keep up with the FSD, a slower rescan is requested. The stage is asked to move at half speed and the co-ordinate flow circuits are asked to transmit only alternate passes of the flying spot or "one-half density". In this way the peak data rates are halved while the scan line separation is held sufficiently constant. Should the road fiducial remain unfound, the film is moved in and out one frame and the picture is rescanned. This occurs if the film fails to stop properly due to substandard binary data box quality or hardware failure.

Fiducials are sought by the H-10 subroutine which searches a histogram of digitizations taken along the 45 degree slope of the fiducial arms. The fiducial arms must be straight for this procedure to work reliably. In Fig. 7 we also see that FILTER calls subroutine DIAG to save all of the gated points for possible later use by a manual filter technique.

FILTER collects bubble density information from the histogram pulse in each twenty point byte. In real time no correction is made for the angle between the flying spot and the track. The average angle based on the chord is determined in the geometry program. A chord to arc length correction will be made in the geometry program. We have found the edge of a photograph to give useful geometry data but erroneous bubble density data since the bubble image size is shrinking to zero. We now take bubble density information only within a smaller area. At the merge of two tracks we do not take bubble density data for that byte. No bubble density data is taken if there is a long gap in the string of track points. The bubble density data is an accumulation of the total number of scans, hits and gaps. Each digitization is a hit and a gap is composed of one or more contiguous misses.

Our FILTER routine initializes a track in its road with some difficulty if there are many tracks in the byte. For this reason we scan the pictures against the beam direction so as to allow track initialization under the more favourable conditions away from the vertex.

3. Post Real Time HAZE

After the scan HAZE checks the result as shown in Fig. 8, a parabolic fit on the film checks for bad points located transverse to the track by more than 30 microns. After the track passes the transverse test a check is made that no gap of more than 30% of the track is devoid of master points. If the track passes this longitudinal test it is accepted.

Rejected tracks may be inspected and repaired if possible by on-line manual filter or by off-line manual filter as mentioned in section I.

In order to make the roads fit well, two separate routines serve the Y-magnification and the rotation angle and X-magnification respectively as shown in Fig. 8. In both routines the rough scan table co-ordinates are compared with the precise FSD co-ordinates in order to cause the first to agree with the second on the average. These servo-subroutines have solved our road-fit problems. The film is stopped by the FSD when the correct binary data box is read. A search box for the road fiducial is placed in a position determined by the average position where the road fiducial is found. This is done by the RF00 subroutine shown in Fig. 8. These servo-subroutines are good examples of how production problems can be solved by software instead of by hardware.

VI. COMPUTED FIT SELECTIONS

We have outlined the fit selection process in section I. We will now describe this important use of FSD bubble density measurements in greater detail.

After some hardware and software debugging we have been able to measure bubble density with the FSD to a 15% standard deviation. This result was obtained by selecting a sample of 4-constraint events that had unambiguous kinematic fit. This distribution of the percentage of difference between the measured and expected bubble densities is approximately normal and its standard deviation is about 15%.

In each view the measured bubble density is corrected for the number of spurious misses per hit. Our current data indicates that there are three spurious misses per one hundred hits.

The next part of the bubble density calculations concerns itself with checking the consistency of the bubble density measurement in the three views. To begin with, those tracks which dip by more than 60° are omitted from the analysis. From the mass and measured momentum the predicted chamber bubble density for each track is computed from the inverse velocity squared law.

This predicted bubble density is then carried to the film in each view. The ratio of the predicted bubble density to the measured bubble density is obtained for each of the remaining views. The ratios are required to agree so as to indicate the correct answer by an agreement of two of the three.

The mass set is then tested by the minimizing chi-squared of a function of the misses predicted and measured while adjusting one parameter which is the bubble density of the beam averaged over the three views.

In our terminology an event which has a positive missing mass is completely acceptable. Those which have negative missing mass are considered to be no-fits.

The scan technicians are able to label a track with a special comment card. The fit selection program checks these comments which may specify as mass (i.e. π -μ-e) or which may indicate that the beam track is overlayed on one view and will have two times minimum bubble density.

The program allows a bias in favour of 4-c fits over 1-c fits. The probability for the bubble density fit is multiplied by the probability for the kinematic fit to get an overall probability for the event. These probabilities are compared with thresholds and the best fits are selected.

Currently we find that human event selection agrees with the computed selection for fits. However, the computed selection yields twice as many no-fits as the human selection. We find by inspection that about 5% of our two prongs and 15% of our four-prongs are no-fits.

VII. SOME FUTURE PLANS FOR USE OF BROOKHAVEN BCG FSD's.

The 70 mm FSD (BNL MARK II) is being turned on for the 30 and 80 in. chambers. One experiment is ready in each chamber. The 70 mm machine has been transmitting co-ordinates for a few months and it has been run under limited control of the HAZE program. We expect to be providing useful track measurements during the winter of 1965.

We will remain as IBM 7094 users after the next Brookhaven AMD general purpose computer is installed some time in 1966. Our FSD production time will increase from 30 hours to 60 hours per week during 1965. Eventually the Brookhaven BCG expects to use most of the IBM 7094 time. A large fraction of this will be used for our two FSD's.

ACKNOWLEDGEMENTS

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TABLE I

Logistics of the analysis of 10,000 $\pi^- + p$ events with the HPD system

Operation	No. of Events (in units of 1,000)	Time to Process Events (in hours)
Scan and predigitize	10	1,000
35 mm FSD	10	130
FOG	9	4.5
Two-prong events:	7	8.5
(CLOUDY 208		2.5)
(CLOUDY 209		4.5)
(S.C. FAIR		1.5)
Four-prong events:	2	7.5
(CLOUDY 208		1.5)
(CLOUDY 209		5.0)
(S.C. FAIR		1.0)

Figure captions

Fig. 1	BNL 35 mm HPD system.
Fig. 2	BNL 35 mm HPD system prior to HAZE.
Fig. 3	BNL 35 mm HPD system from HAZE through FOG.
Fig. 4	BNL 35 mm HPD system after FOG.
Fig. 5	HAZE.
Fig. 6	HAZE (pre-real time).
Fig. 7	HAZE (real time).
Fig. 8	HAZE (post-real time).

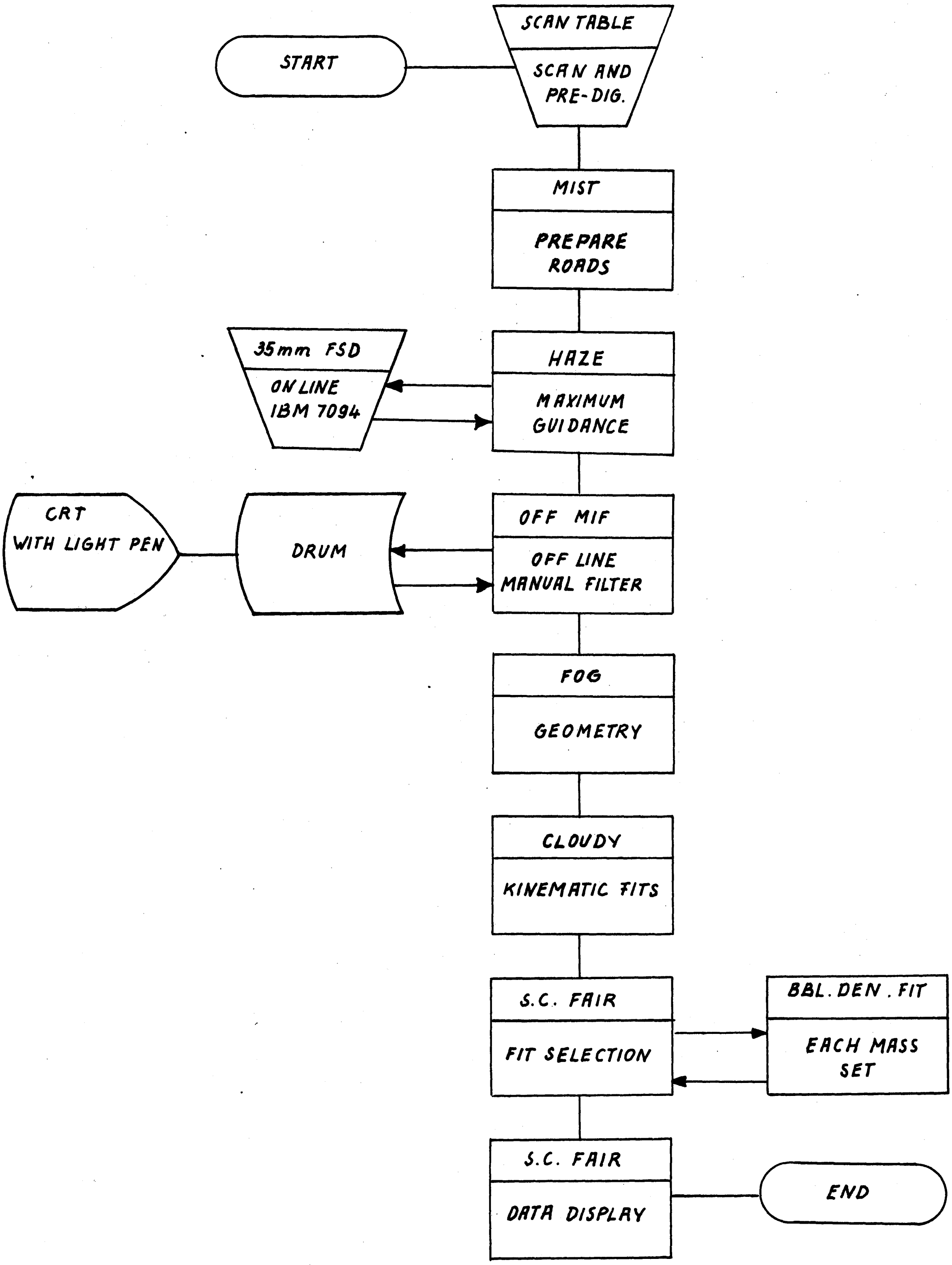
START
SCAN TABLE
SCAN AND PRE-DIG.
MIST
PREPARE ROADS
35mm FSD
ON LINE IBM 7094
HAZE
MAXIMUM GUIDANCE
CRT WITH LIGHT PEN
DRUM
OFF MIF
OFF LINE MANUAL FILTER
FOG
GEOMETRY
CLOUDY
KINEMATIC FITS
S.C. FAIR
FIT SELECTION
BBL.DEN.FIT
EACH MASS SET
S.C. FAIR
DATA DISPLAY
END

Fig. 1

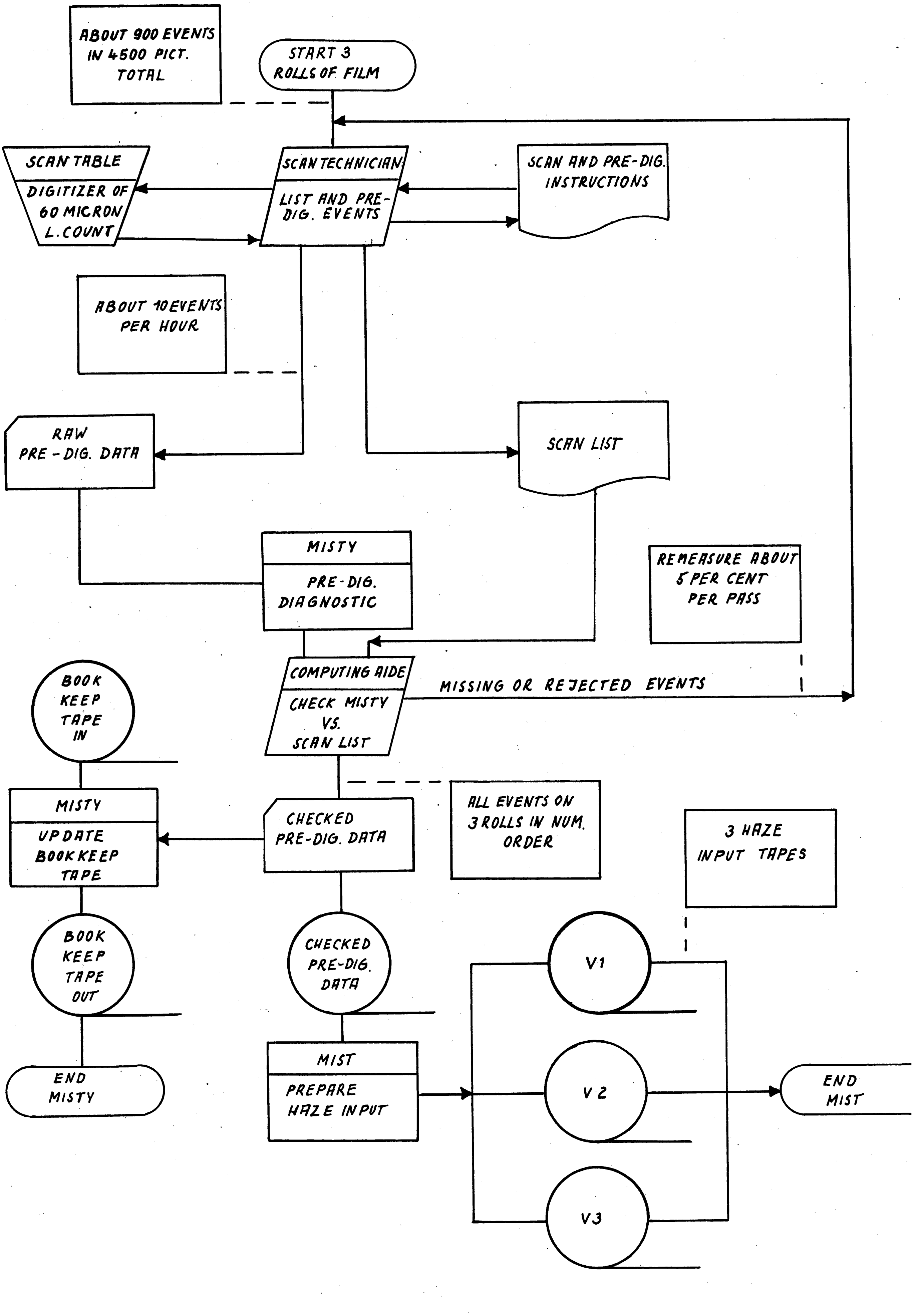
ABOUT 900 EVENTS IN 4500 PICT. TOTAL
START 3 ROLLS OF FILM
SCAN TABLE
DIGITIZER OF 60 MICRON L. COUNT
SCAN TECHNICIAN
LIST AND PRE-DIG. EVENTS
SCAN AND PRE-DIG. INSTRUCTIONS
ABOUT 10 EVENTS PER HOUR
RAW PRE-DIG. DATA
SCAN LIST
MISTY
PRE-DIG. DIAGNOSTIC
REMEASURE ABOUT 5 PER CENT PER PASS
COMPUTING AIDE
CHECK MISTY VS. SCAN LIST
MISSING OR REJECTED EVENTS
BOOK KEEP TAPE IN
MISTY
UPDATE BOOK KEEP TAPE
CHECKED PRE-DIG. DATA
ALL EVENTS ON 3 ROLLS IN NUM. ORDER
3 HAZE INPUT TAPES
BOOK KEEP TAPE OUT
CHECKED PRE-DIG. DATA
V1
V2
V3
END MISTY
MIST
PREPARE HAZE INPUT
END MIST

Fig. 2

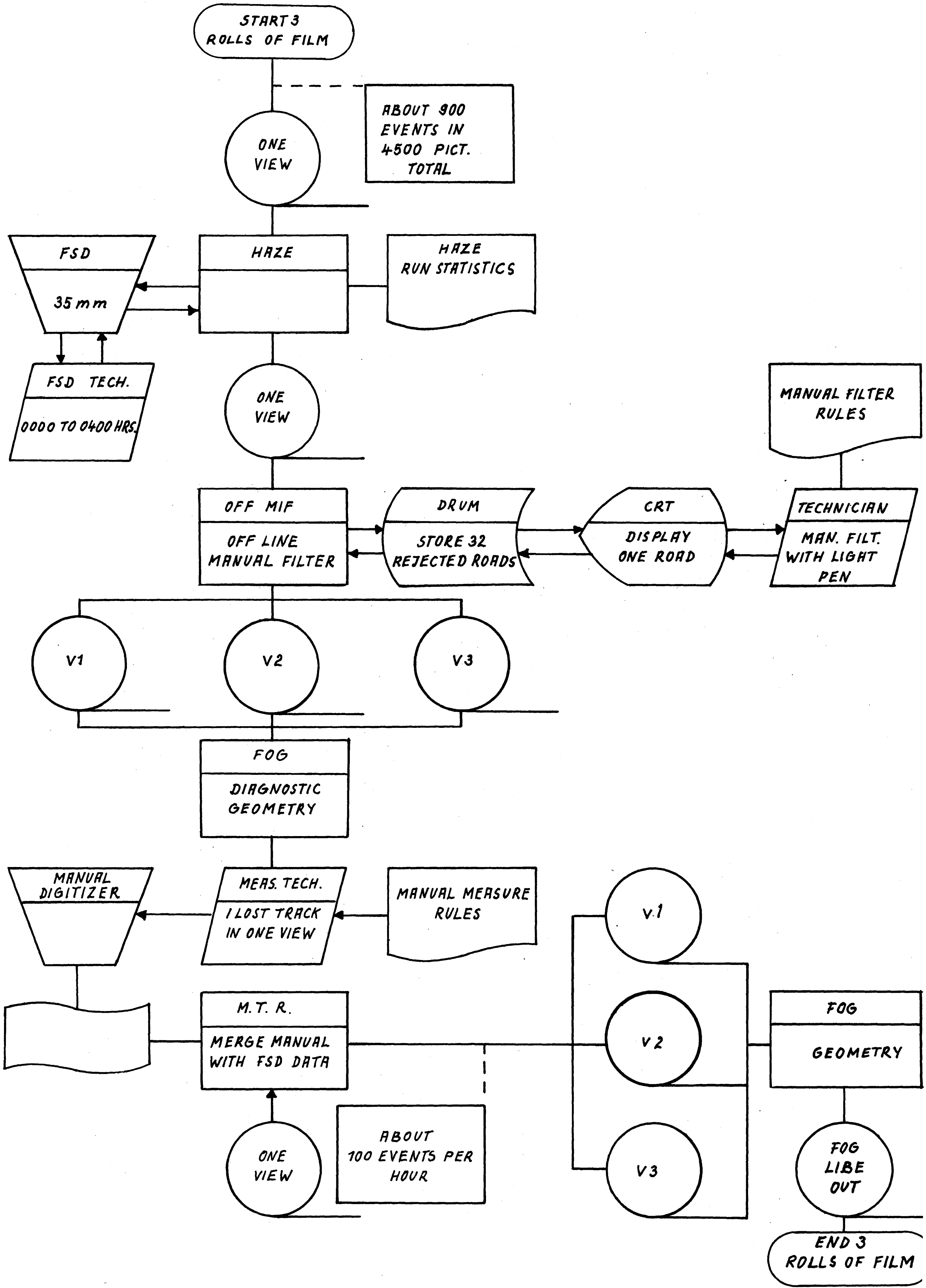
START 3 ROLLS OF FILM
ABOUT 900 EVENTS IN 4500 PICT. TOTAL
ONE VIEW
FSD
35 mm
HAZE
HAZE RUN STATISTICS
FSD TECH.
0000 TO 0400 HRS.
ONE VIEW
MANUAL FILTER RULES
OFF MIF
OFF LINE MANUAL FILTER
DRUM
STORE 32 REJECTED ROADS
CRT
DISPLAY ONE ROAD
TECHNICIAN
MAN. FILT. WITH LIGHT PEN
V1
V2
V3
FOG
DIAGNOSTIC GEOMETRY
MANUAL DIGITIZER
MEAS. TECH.
1 LOST TRACK IN ONE VIEW
MANUAL MEASURE RULES
V1
V2
V3
M.T.R.
MERGE MANUAL WITH FSD DATA
FOG
GEOMETRY
ONE VIEW
ABOUT 100 EVENTS PER HOUR
FOG LIBE OUT
END 3 ROLLS OF FILM

Fig. 3

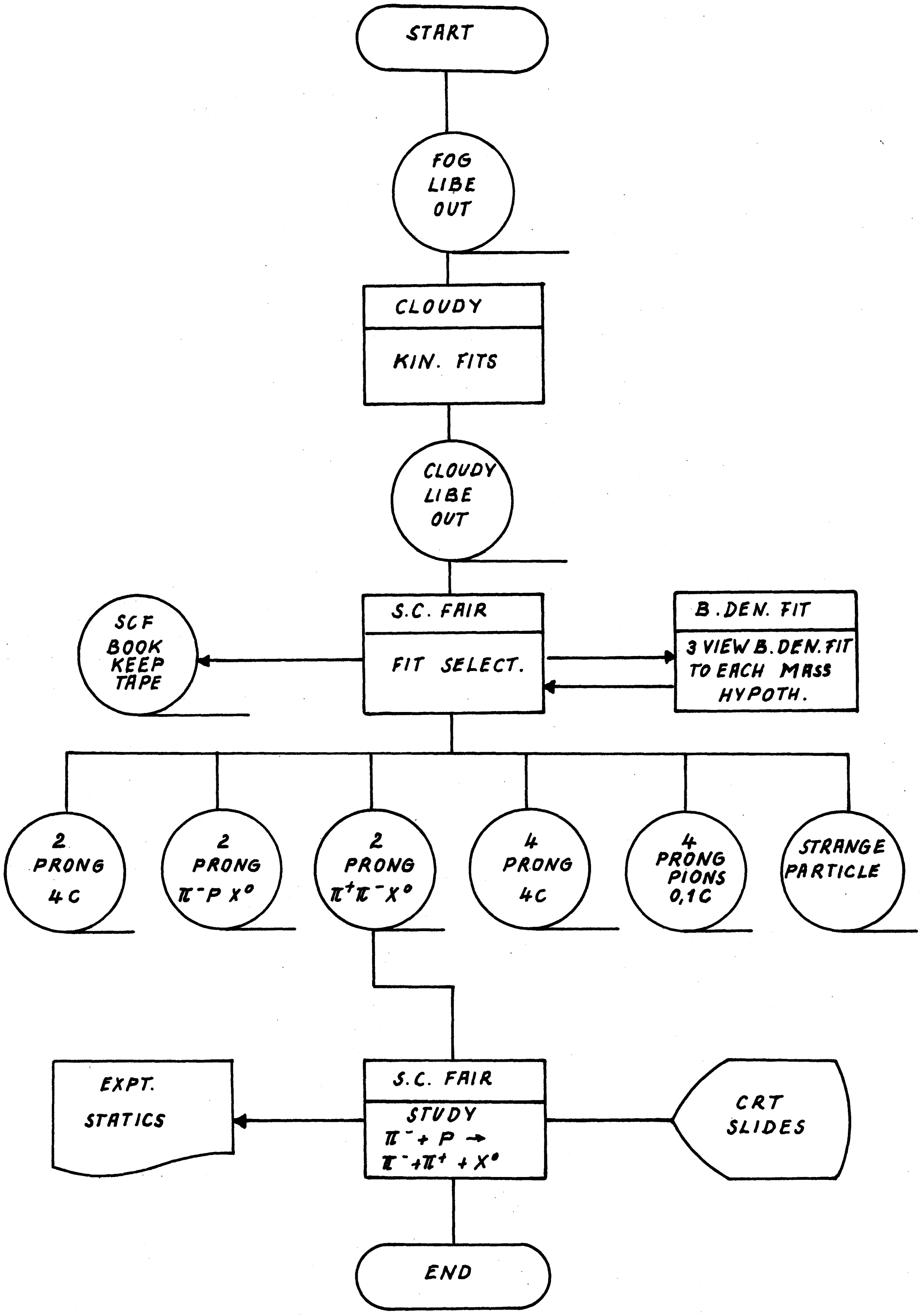
START
FOG LIBE OUT
CLOUDY
KIN. FITS
CLOUDY LIBE OUT
S.C. FAIR
FIT SELECT.
SCF BOOK KEEP TAPE
B.DEN. FIT
3 VIEW B.DEN.FIT TO EACH MASS HYPOTH.
2 PRONG 4C
2 PRONG $\pi^- P X^0$
2 PRONG $\pi^+\pi^- X^0$
4 PRONG 4C
4 PRONG PIONS 0,1C
STRANGE PARTICLE
S.C. FAIR
STUDY $\pi^- + P \rightarrow \pi^- + \pi^+ + X^0$
EXPT. STATICS
CRT SLIDES
END

Fig. 4

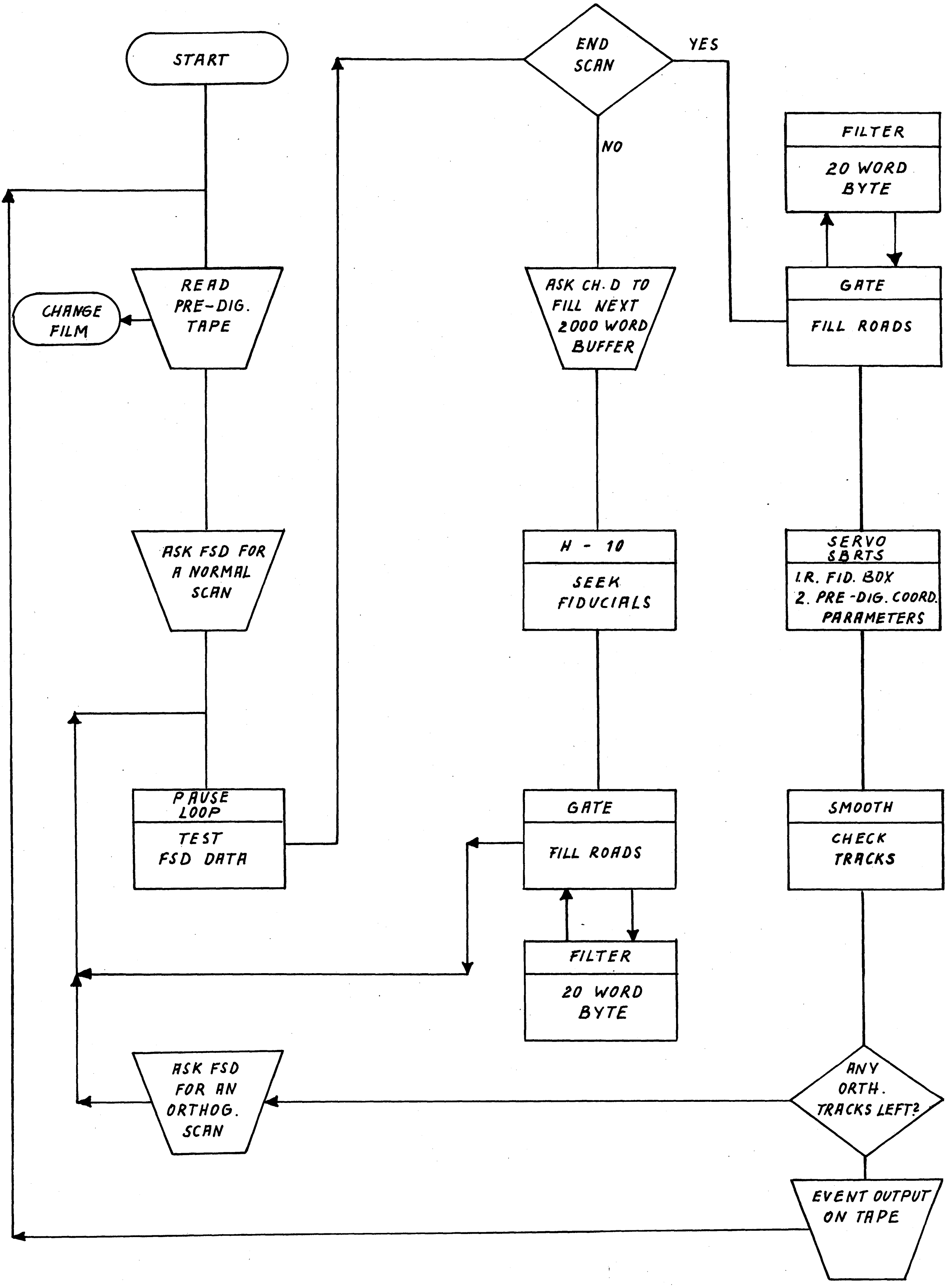
START
CHANGE FILM
READ PRE-DIG. TAPE
ASK FSD FOR A NORMAL SCAN
PAUSE LOOP
TEST FSD DATA
ASK FSD FOR AN ORTHOG. SCAN
END SCAN
YES
NO
ASK CH. D TO FILL NEXT 2000 WORD BUFFER
H - 10
SEEK FIDUCIALS
GATE
FILL ROADS
FILTER
20 WORD BYTE
FILTER
20 WORD BYTE
GATE
FILL ROADS
SERVO SBRTS
1. R. FID. BOX
2. PRE-DIG. COORD. PARAMETERS
SMOOTH
CHECK TRACKS
ANY ORTH. TRACKS LEFT?
EVENT OUTPUT ON TAPE

Fig. 5

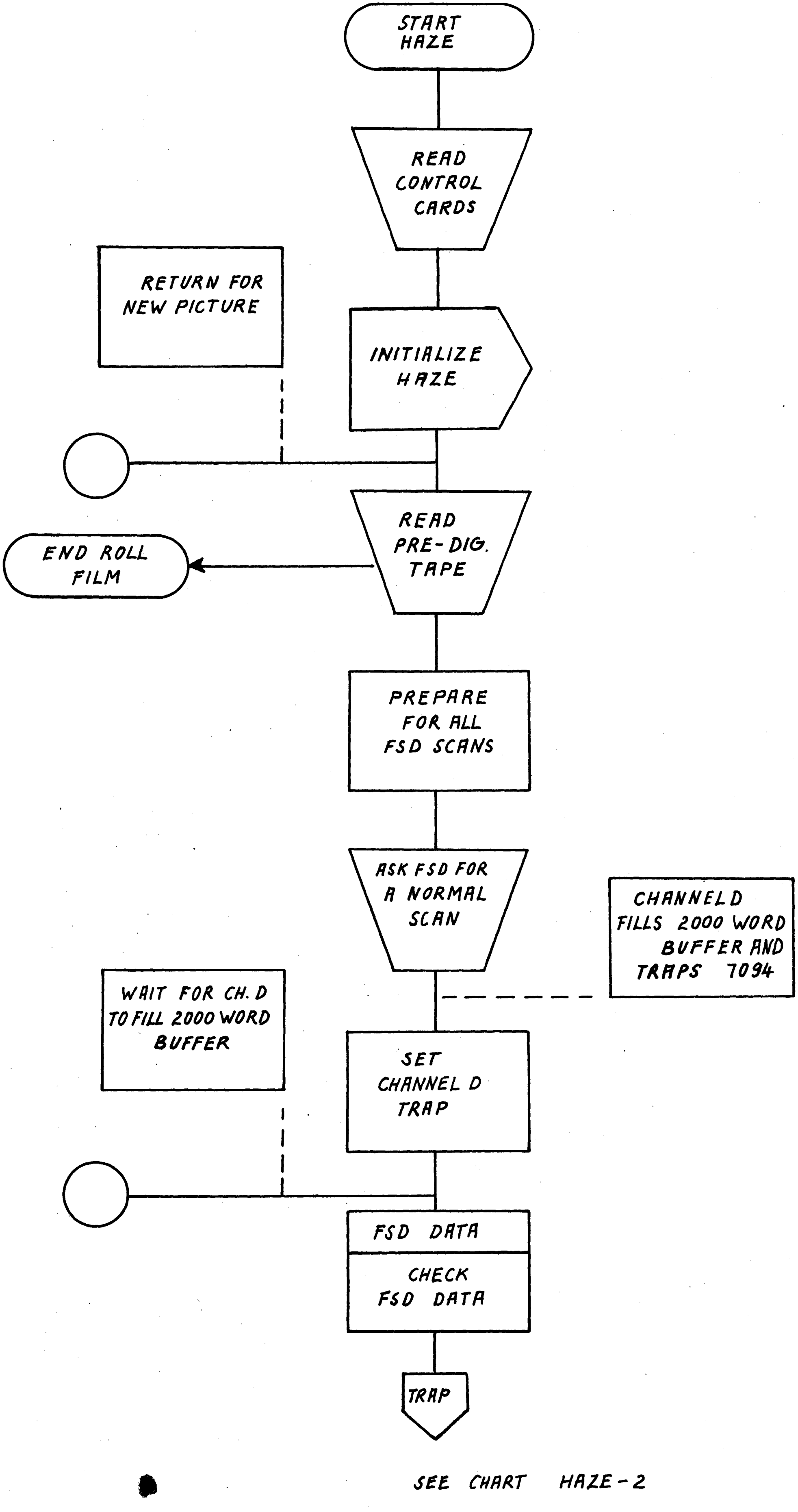
START HAZE
READ CONTROL CARDS
RETURN FOR NEW PICTURE
INITIALIZE HAZE
READ PRE-DIG. TAPE
END ROLL FILM
PREPARE FOR ALL FSD SCANS
ASK FSD FOR A NORMAL SCAN
CHANNEL D FILLS 2000 WORD BUFFER AND TRAPS 7094
WAIT FOR CH. D TO FILL 2000 WORD BUFFER
SET CHANNEL D TRAP
FSD DATA
CHECK FSD DATA
TRAP
SEE CHART HAZE-2

Fig. 6

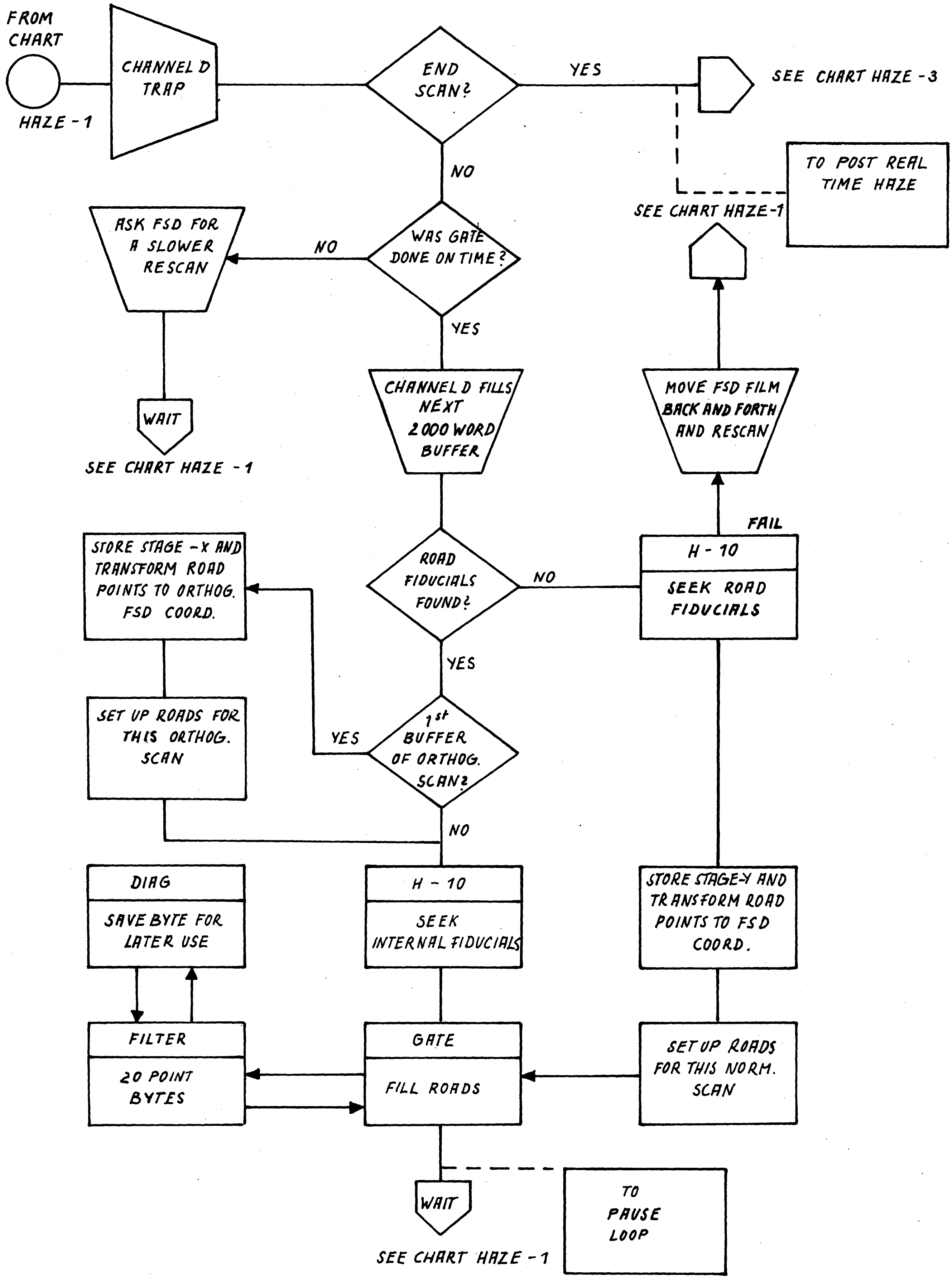
FROM CHART
HAZE - 1
CHANNEL D TRAP
END SCAN?
YES
SEE CHART HAZE -3
NO
TO POST REAL TIME HAZE
SEE CHART HAZE-1
ASK FSD FOR A SLOWER RESCAN
NO
WAS GATE DONE ON TIME?
YES
WAIT
SEE CHART HAZE - 1
CHANNEL D FILLS NEXT 2000 WORD BUFFER
MOVE FSD FILM BACK AND FORTH AND RESCAN
FAIL
STORE STAGE -X AND TRANSFORM ROAD POINTS TO ORTHOG. FSD COORD.
ROAD FIDUCIALS FOUND?
NO
H - 10
SEEK ROAD FIDUCIALS
YES
SET UP ROADS FOR THIS ORTHOG. SCAN
YES
1st BUFFER OF ORTHOG. SCAN?
NO
DIAG
SAVE BYTE FOR LATER USE
H - 10
SEEK INTERNAL FIDUCIALS
STORE STAGE-Y AND TRANSFORM ROAD POINTS TO FSD COORD.
FILTER
20 POINT BYTES
GATE
FILL ROADS
SET UP ROADS FOR THIS NORM. SCAN
WAIT
SEE CHART HAZE - 1
TO PAUSE LOOP

Fig. 7

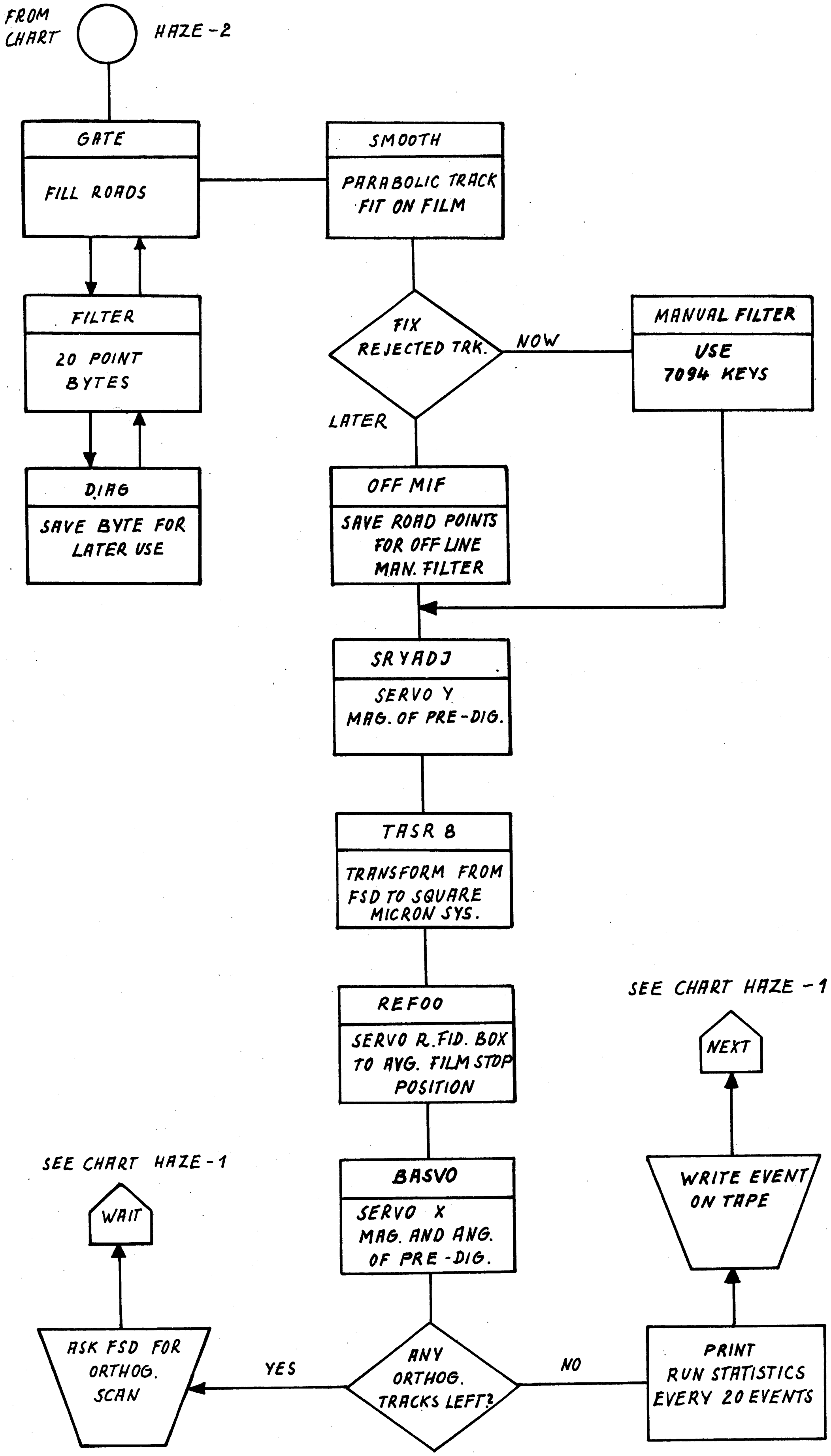
FROM CHART
HAZE-2
GATE
FILL ROADS
SMOOTH
PARABOLIC TRACK FIT ON FILM
FILTER
20 POINT BYTES
FIX REJECTED TRK.
NOW
MANUAL FILTER
USE 7094 KEYS
LATER
DIAG
SAVE BYTE FOR LATER USE
OFF MIF
SAVE ROAD POINTS FOR OFF LINE MAN. FILTER
SRYADJ
SERVO Y MAG. OF PRE-DIG.
TASR 8
TRANSFORM FROM FSD TO SQUARE MICRON SYS.
SEE CHART HAZE-1
REFOO
SERVO R. FID. BOX TO AVG. FILM STOP POSITION
NEXT
SEE CHART HAZE-1
WAIT
BASVO
SERVO X MAG. AND ANG. OF PRE-DIG.
WRITE EVENT ON TAPE
ASK FSD FOR ORTHOG. SCAN
YES
ANY ORTHOG. TRACKS LEFT?
NO
PRINT RUN STATISTICS EVERY 20 EVENTS

Fig. 8

DISCUSSION

ROYSTON: What is the difference between the road fiducials and the chamber fiducials?

STRAND: The road fiducials are encountered before the picture in the HPD scan. They are predigitized on the scan table and are used to calculate the transformation from the scan table co-ordinate system to the HPD system. The chamber fiducials are used for reconstruction of the event.

BLOCH: Do you think that a least count of 60 microns, on the film, for the predigitizer is satisfactory?

STRAND: Our new predigitizers will have a 30 micron least count so that the filter program can use smaller roads. This will increase the efficiency of the filter program.

BLOCH: For your ionization measurements, how do you deal with tangent tracks?

STRAND: δ-rays may cause spurious gaps by shading the track. For a perfectly black track the program allows for 3 misses in 100 hits. Parallel beam tracks are noted while predigitizing and are specially treated. Merging tracks are detected in the filter program and for the region where the tracks are very close the bubble density information is not used.

BENOT: Is a 40 micron scan line separation satisfactory for bubble density measurements?

STRAND: It is a compromise between scan speed and accuracy of bubble density measurement, the FSD bubble width is about 40 microns, so this is satisfactory.