

USE OF GRAPHICS IN THE DESIGN OFFICE
AT THE MILITARY AIRCRAFT DIVISION
OF THE BRITISH AIRCRAFT CORPORATION

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SUMMARY

This paper describes the CAD/CAM system which has been developed by the Military Aircraft Division of the British Aircraft Corporation, shows the uses to which it has been put, and outlines current development of the system. The system supports batch, time sharing, and fully interactive graphic processing. Engineers using the system may switch between these methods of data processing and problem solving to make the best use of the available resources. It is concluded that the introduction of on-line computing in the form of teletypes, storage tubes, and fully interactive graphics has resulted in large increases in productivity and reduced timescales in the geometric computing, numerical lofting and part programming areas, together with a greater utilisation of the system in the technical departments.

DEVELOPMENT OF THE SYSTEM

The system has been developed from three programs.

- 1. The BAC Numerical Master Geometry Program (NMG)

This is a language based surface definition, interrogation and machining program. This program, developed by BAC, was introduced into the Design Office during 1965/1966. The inputs and outputs of the program are, in general, finite three dimensional curves and surfaces defining the shape of an aircraft.

- 2. A.P.T.

This language based, 2½ - 3 dimensional component definition and machining program, became available to BAC when the IBM APT system was released in 1968. The program has considerable geometric and arithmetical calculation power, but bounded geometry could only be created by cutter motion statements. It is adequate, but not very suitable, for producing component drawing.

This is a fully interactive 2 - 2½ dimensional component definition and machining language. All input to the program is entered using the light pen and keyboard of the IBM 2250. 2 dimensional component drawings can easily be produced.

The starting point for the development of the system was, therefore, two complementary programs, (APT and NMG) which have some overlapping and some incompatible features, but whose only interface was the manual transcription of data, e.g.,

Complementary to the extent that:-

NMG is concerned with aircraft surfaces, whereas APT is concerned with the component geometry - lines - circles, etc.

Overlapping in that:-

Both systems use transformation matrices, interpolated curves, etc.

Incompatible to the extent that:-

- 1) Data derived from the NMG system could not be used in APT and vice-versa, e.g.,

Curves used on APT are similar but not identical to NMG spline curves.

- 2) NMG surfaces could not be machined in APT.

This situation was clearly unacceptable, and it was decided that extensive modifications to the IBM APT programs would have to be made in order to achieve compatibility, and to interface it to the NMG system.

The following facilities were, therefore, added to the APT system:-

- 1) Metric capability included
- 2) Capability to READ and WRITE NMG Files (Access and write, curves, surfaces, and reference systems.)
- 3) Capability to use NMG curves in place of Tabcyls.
- 4) Matrix definitions were changed to be compatible with NMG
- 5) Use of NMG surfaces as APT part, check, or drive surfaces
- 6) Restructured to fit into 140K of core.

The modified APT program which also included extensive modification to improve efficiency was named APT 140 and released in 1971. As expected the combined APT/NMG system provided a powerful geometric computing lofting and N/C machining facility, limited only by the restrictions of batch processing.

Since then the system has been further developed (Fig. 1) to interface with the interactive N/C graphics program, to run semi-interactively under the IBM TSO system using teletypes and remote displays, and to run fully interactively using an IBM 2250.

The interface with the N/C graphics program is via a file which contains component descriptions in the form of bounded geometry and text.

Interactive processing has been achieved by providing the APT and NMG programs with restart facilities, and common input, output, and display files; all of which are under the control of a terminal program. The main functions of the terminal are:-

- 1) Preparation of text input (card images)
- 2) Modifications of text input
- 3) Inspection of text output
- 4) Storage and retrieval of text input
- 5) Graphical preparation of input
- 6) 3 Dimensional picture preparation and manipulation
- 7) Preparation of plots
- 8) Loading program modules.

The introduction of on line processing and graphic displays, together with the 'program independent' terminal facility has provided a powerful impetus to extending the use of the Numerical Master Geometry system to the preparation and verification of geometric information for technical calculations. e.g., Generation of grids for structural analysis and aerodynamic calculations.

USE OF THE SYSTEM

The system is extensively used at all stages of design and production as described in the following examples. When considering these examples it is important to remember that for all applications the designer, loftsmen, engineer, part programmer etc., may switch between BATCH, TIME SHARING and FULLY INTERACTIVE methods of data preparation or problem solution.

The method chosen will depend not only on the most 'economical' method of producing the desired result, but on the priority of the job, the departmental loading, computer resources available etc. This flexibility of operation has been found to be of fundamental importance not only because particular resources may be withdrawn due to breakdowns, but because relative priorities change with time, and jobs started in batch may be completed interactively and vice versa.

1) Lines Definition Fig. 2, 3, 4, 5

The project designer prepares a scheme, which is passed to the linesman who uses the NMG system to convert the scheme into the final aircraft lines which are stored as a surface on the NMG Master File. The scheme will normally consist of a mixture of dimensioned and drawn data, and the linesman will use a mixture of calculation and drawing to establish the set of sections which are submitted to the NMG program for conversion into a surface. The process of achieving a fair set of lines is iterative, the designer will examine definition data, water lines and level lines between iterations and modify the definition sections until a smooth set of lines has been obtained (Fig. 3 and 4). When he is satisfied with the surface it will be stored on the master file, and a surface definition drawing will be issued. (Fig. 5).

Surfaces representing the whole aircraft (Fig. 6) including internal and external surfaces (Fig. 7) are generated and stored on the master tape.

All information in the master tape is stored in the basic aircraft reference system.

Surfaces on the master tape are now available for general use. Typical uses for the surfaces are:-

- 2) Nests of sections (Fig. 8)
- 3) Obscuration plots
- 4) Clearance problems (Fig. 9)
- 5) Machining wind tunnel models (Fig. 10)
- 6) Machining form tools (Figs. 11 and 13)
- 7) Generation of new sections which form the outside shape of components (Fig. 12, 13)

Here we see a linesman typing a request for a new section to be generated and plotted. The teletype will only return a listing but a graphic display (Fig. 13) will return a picture which can be checked for errors prior to plotting on the Gerber Draughting machine. Input to the Gerber Draughting Machine is generated by typing the instruction "PLOT GERBER SCALE n" which produces a Gerber input tape of the picture displayed on the screen.

8) Definition and Machining of Large N/C Components

Large N/C components are numerically lofted. The outside shape is taken from the master file, and the details of the internal geometry are added using the component definition languages. The manufacturing drawing issued by the loft carries a reference to the component geometry and the identifiers of the geometric variables. (Fig. 14, 15). To produce the N/C machining tape the part programmer calls up the component geometry and adds his own cutter statements. The cutter path can be checked by superimposing it on the component geometry before producing the final machined component. (Fig. 16).

Fig. 15 shows a typical drawing and component produced using the APT program. Figs. 17 and 18 show a similar component being defined and machined using interactive graphics. Interactive graphics is being increasingly used for N/C lofting and N/C part programming, and the APT program is being modified to extend interactive techniques to three dimensional components (Figs. 19 and 20).

9) Geometric Data for Aerodynamic and Structural Analysis

The generation of data for automatic transfer to aerodynamic and structural analysis programs presents a particularly challenging problem which is receiving increased attention. A frequently encountered task is the generation of a grid of points forming a set of panels.

At face value this would appear to be a simple task, but considerable difficulties and complexities are introduced by:-

- 1) The variety of methods used to specify point locations and panel sizes. This problem is particularly severe for aerodynamic calculations where panel topology is directly linked to aerodynamic theory and must frequently be derived from surface properties such as local chord, span, aspect ratio etc., which are no longer held explicitly in the master model.

- 2) Aerodynamic and structural grids are usually formed on a group of surfaces some of which may overlap (Fig. 21 shows a simple case). A cut through such a group of surfaces results in a set of curves which may easily be drawn, but which are not suitably ordered for subsequent processing to form a grid.
- 3) Only part of the analysis data can be derived from the master model. Local modification may be required, and the data will have to be combined with manually prepared data.
- 4) The format of the output is dependent on the program with which it is to be used.

In the batch processing environment these problems proved sufficiently severe to restrict us to interfaces based on the manual transcription of data. The advent of on line devices has, however, renewed the hope that the problems can be overcome, and Figs. 21 and 22 show a promising method suited to graphic devices which is being investigated.

The grid of Fig. 21 is produced by finding all points of intersection of the lines GL1 etc., with the nest of sections, and it is seen that the picture must be modified in the region of GL4 in order to define a unique set of panel points. On line graphic devices are particularly suitable for generating, checking, and modifying pictures of this type which can be subsequently batch processed to produce panel data. Similarly the structural analysis grid of Fig. 22 can easily be drawn and checked using a graphic device, and be subsequently batch processed to produce point and panel data.

The output data for both grids is written in the appropriate format and stored as card images in the on line 'card' file. From there it can easily be modified and combined with manually prepared data using terminal facilities.

CONCLUSIONS

The addition of on line teletype and graphic facilities to augment the previous batch processing system has resulted in increases in productivity of the order of 50% to 100% in the geometric computing, numerical lofting, and NC programming areas. Timescales for high priority jobs can be reduced even more dramatically. The main factor contributing to this improvement is that the majority of delays encountered in running a fragmented system have been eliminated, e.g., delays associated with conventional data processing:-

Manual Transcription of data

Waiting for cards

Waiting for loading into the computer

Waiting for listings

Waiting for plotting

are avoided.

Streamlined data processing is particularly important when a number of consecutive small jobs have to be run to establish the data for a more substantial task.

Further benefits from the system are that:-

N/C components produced interactively are more often correct first time than those produced using batch processing. On line computing has truly augmented the batch processing system. Graphical displays can be used to check data before embarking on expensive batch processing runs, and users no longer feel obliged to run large jobs to establish as much data as possible overnight in order to avoid a day's delay if anything has been forgotten. The Gerber Draughting machine is released from the task of producing small scale check plots.

The concept of a program and device independent text based system, with common input, output and display files, operating from card checks, typed input or graphically prepared data is proving sound, and is providing a powerful impetus to the use of graphic data processing in all technical departments.

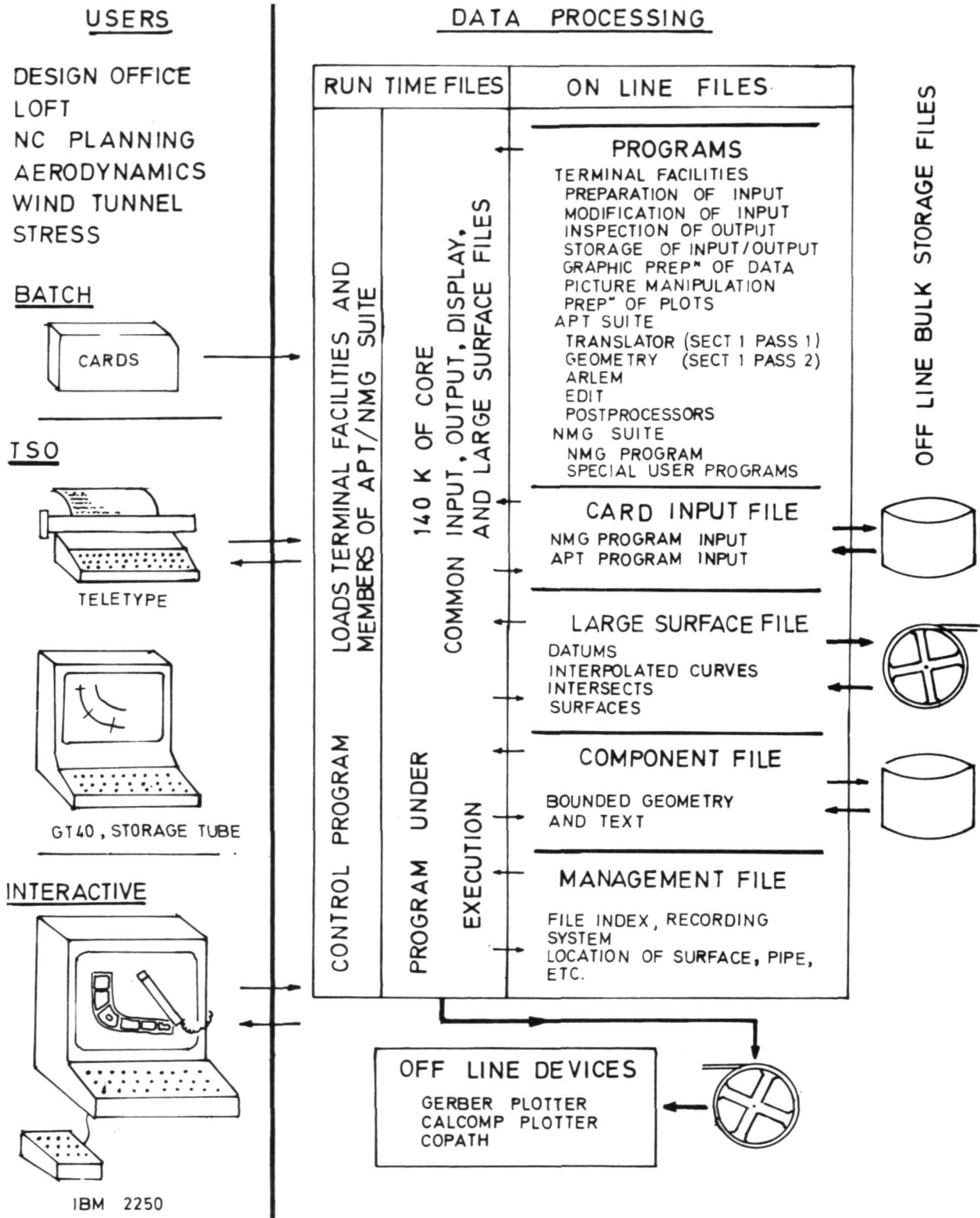


Figure 1.- The CAD/CAM system.

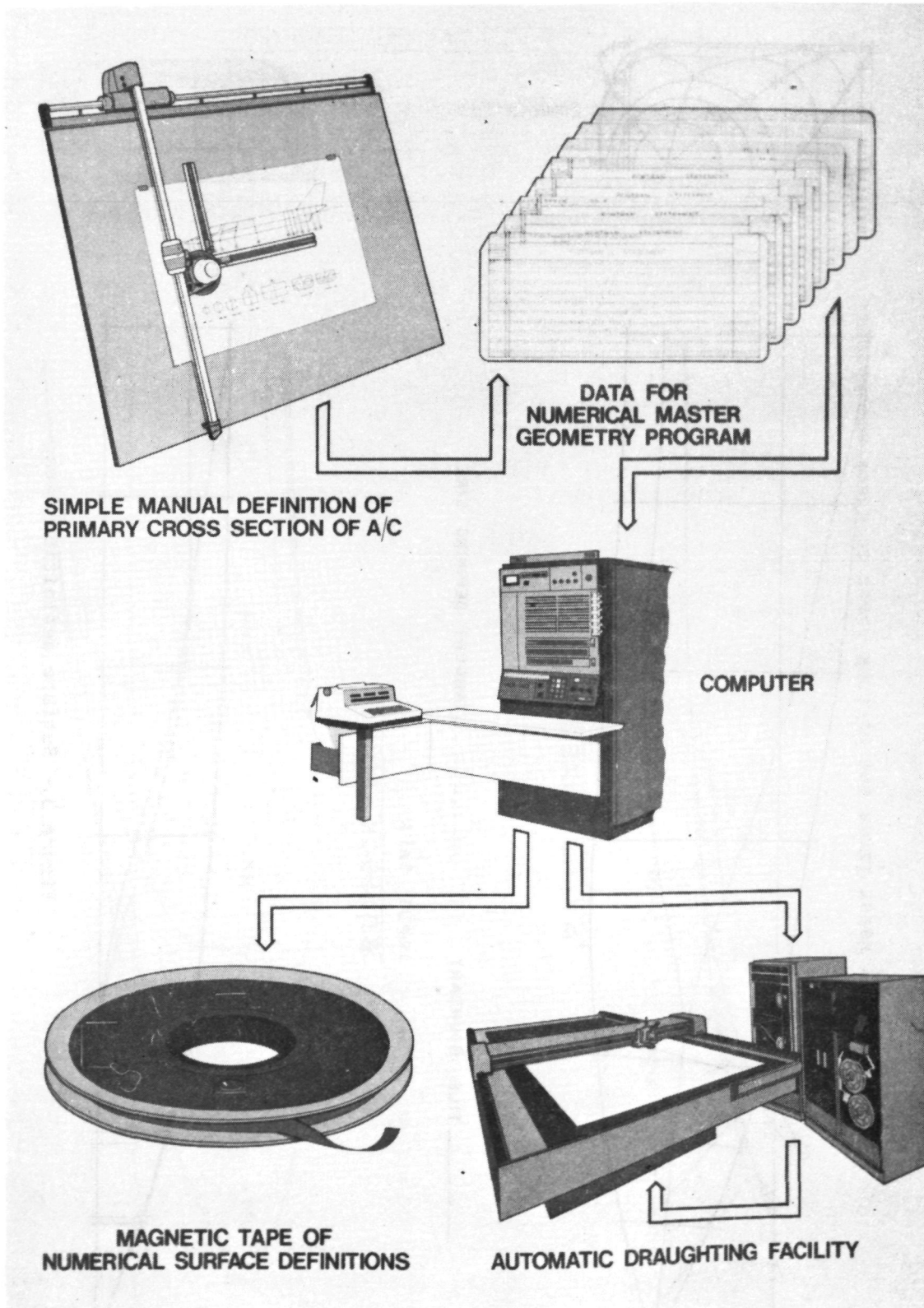
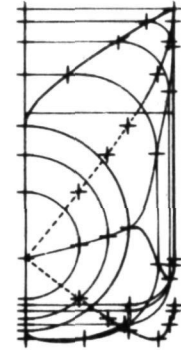
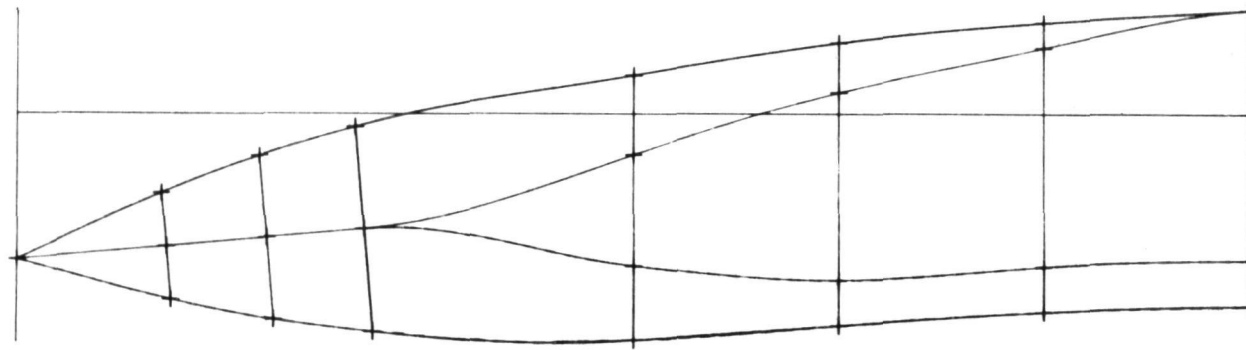


Figure 2.- The Numerical Master Geometry system.



——— TILE BOUNDARY - - - - - TANGENT DEFINING LINE
+ INPUT DATA

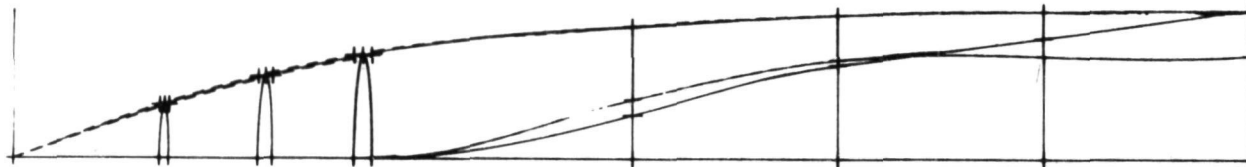
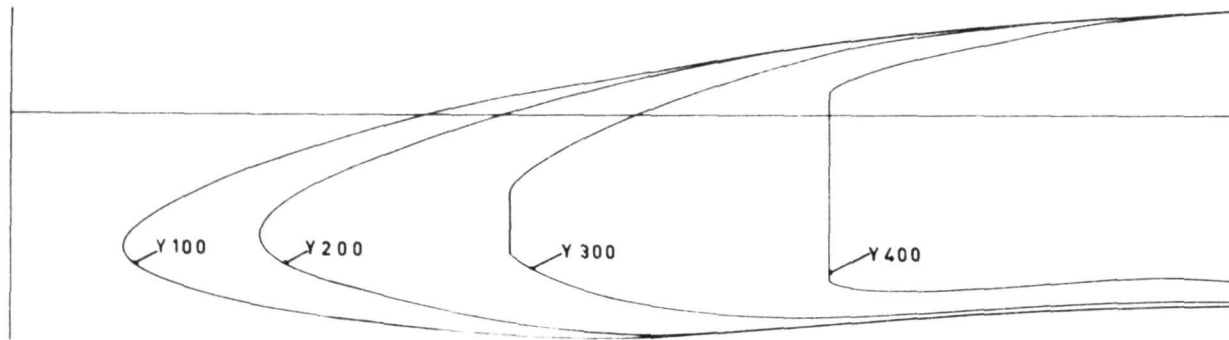


Figure 3.- Surface definition data.



BUTTOCK LINES.



WATER LINES.

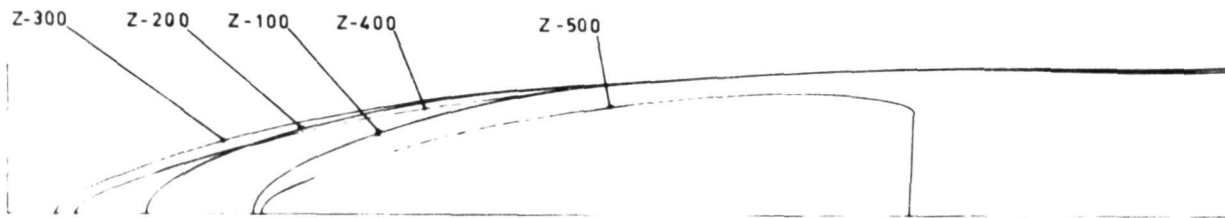
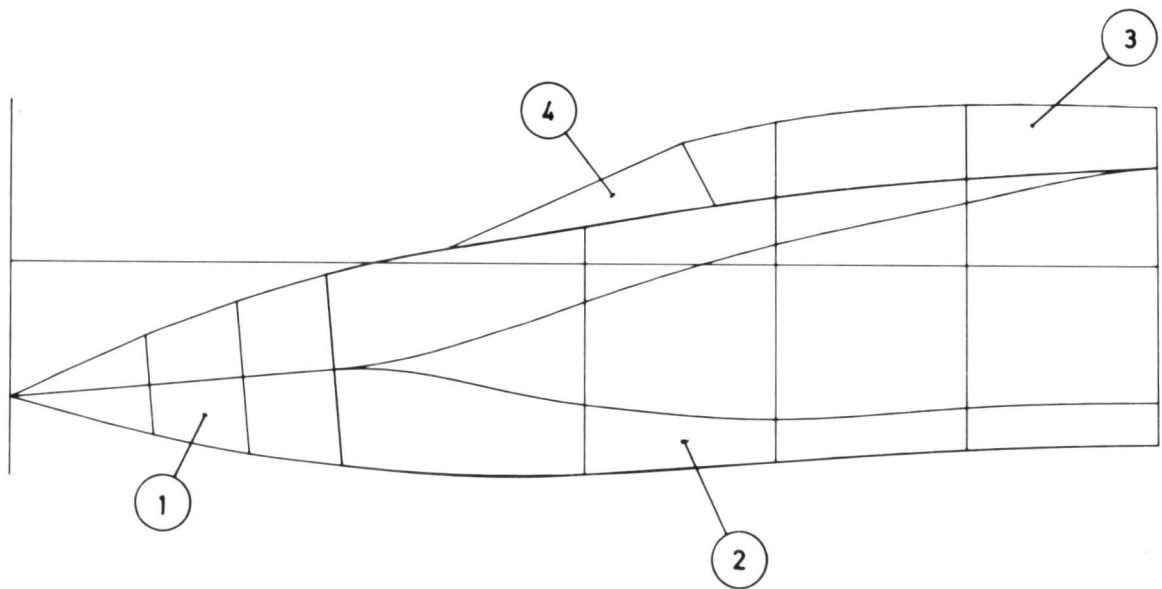
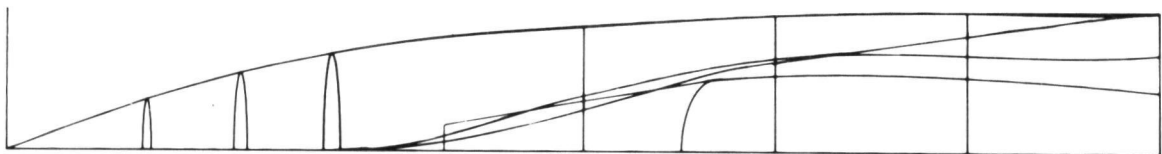


Figure 4.- Water lines and buttock lines to check smoothness.



NOTE
EACH SURFACE IS DRAWN REFERENCING U AND V LINES.



4	D/20/S 40
3	D/20/S 7
2	D/20/S 2
1	D/20/S 1
Nº	ITEM NAME

FILE NAME _DEMOMAST

Figure 5.- Surface definition drawing referencing master files.

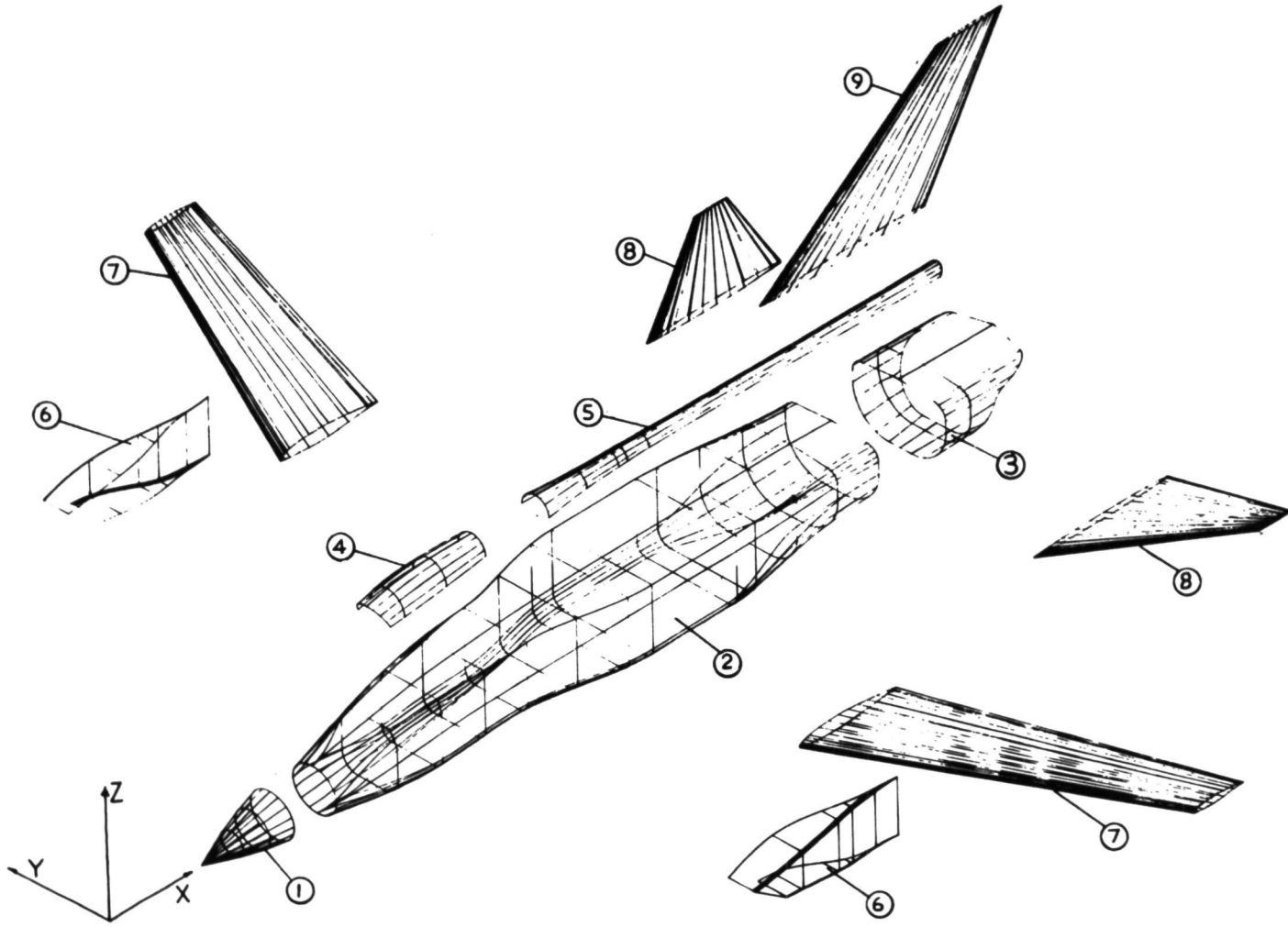


Figure 6.- Isometric view of typical aircraft surfaces.

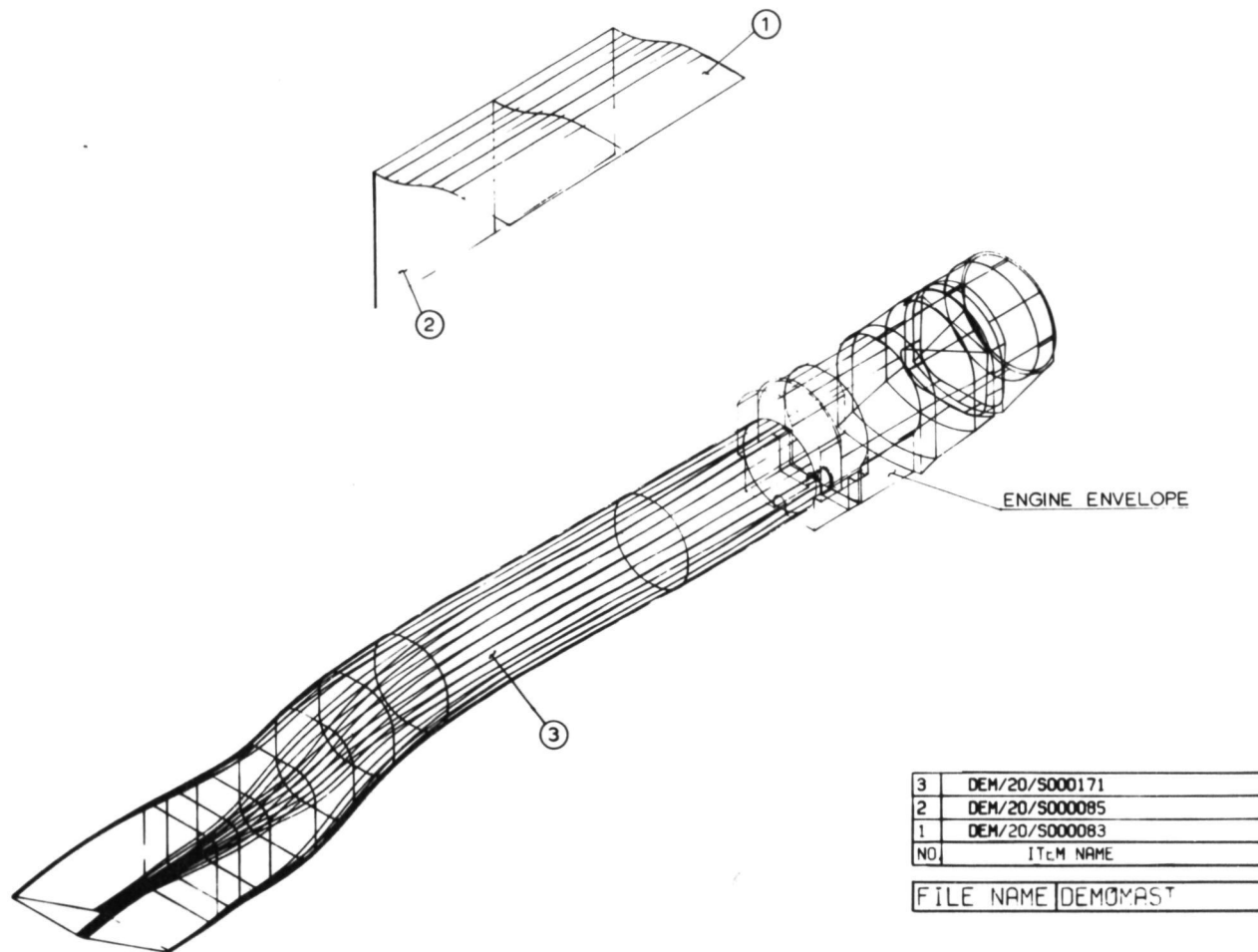


Figure 7.- Surfaces defining duct, engine bay and engine envelope.

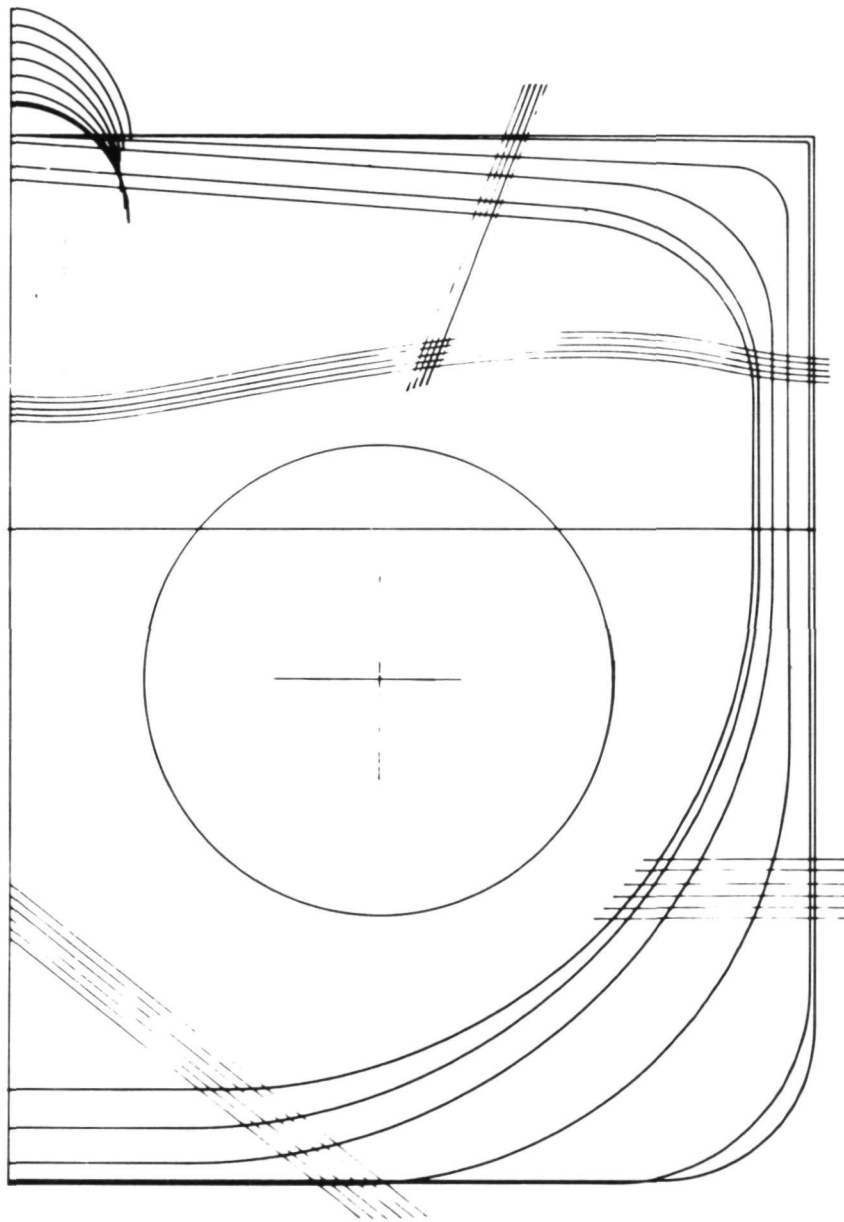


Figure 8.- Nest of sections showing location of internal structure and engine tunnel.

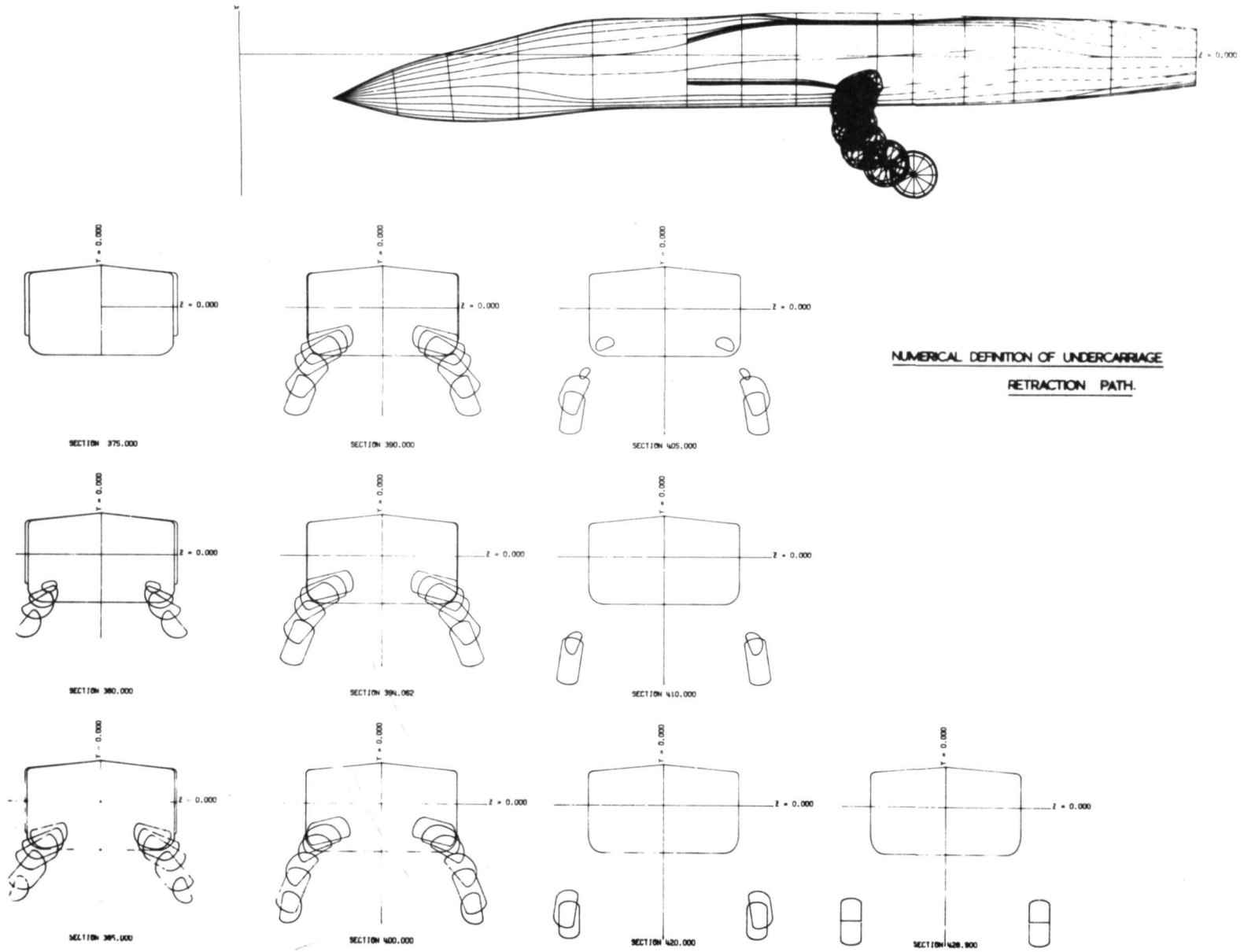


Figure 9.- Clearance checks.

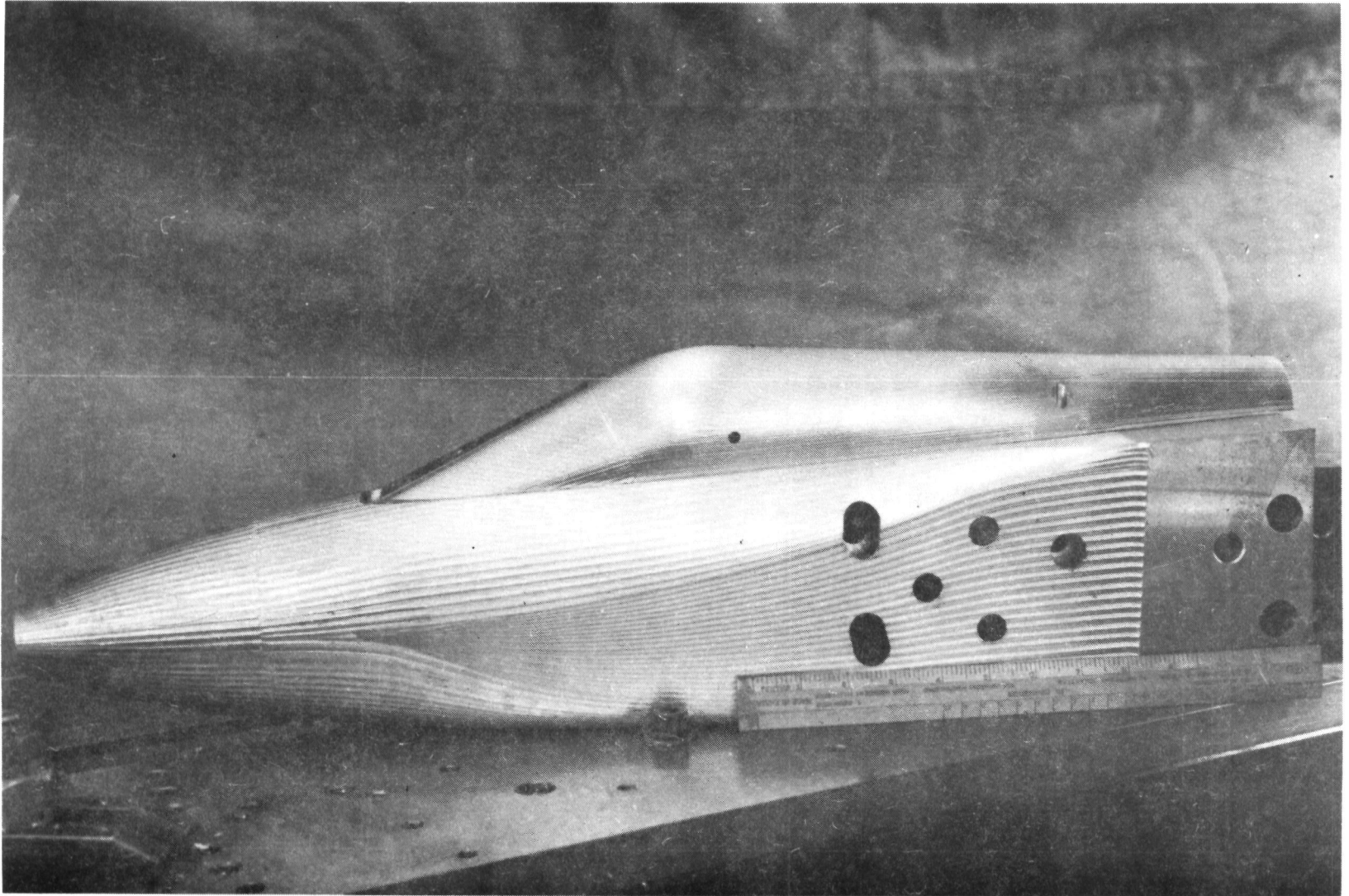


Figure 10.- N/C produced wind tunnel model.

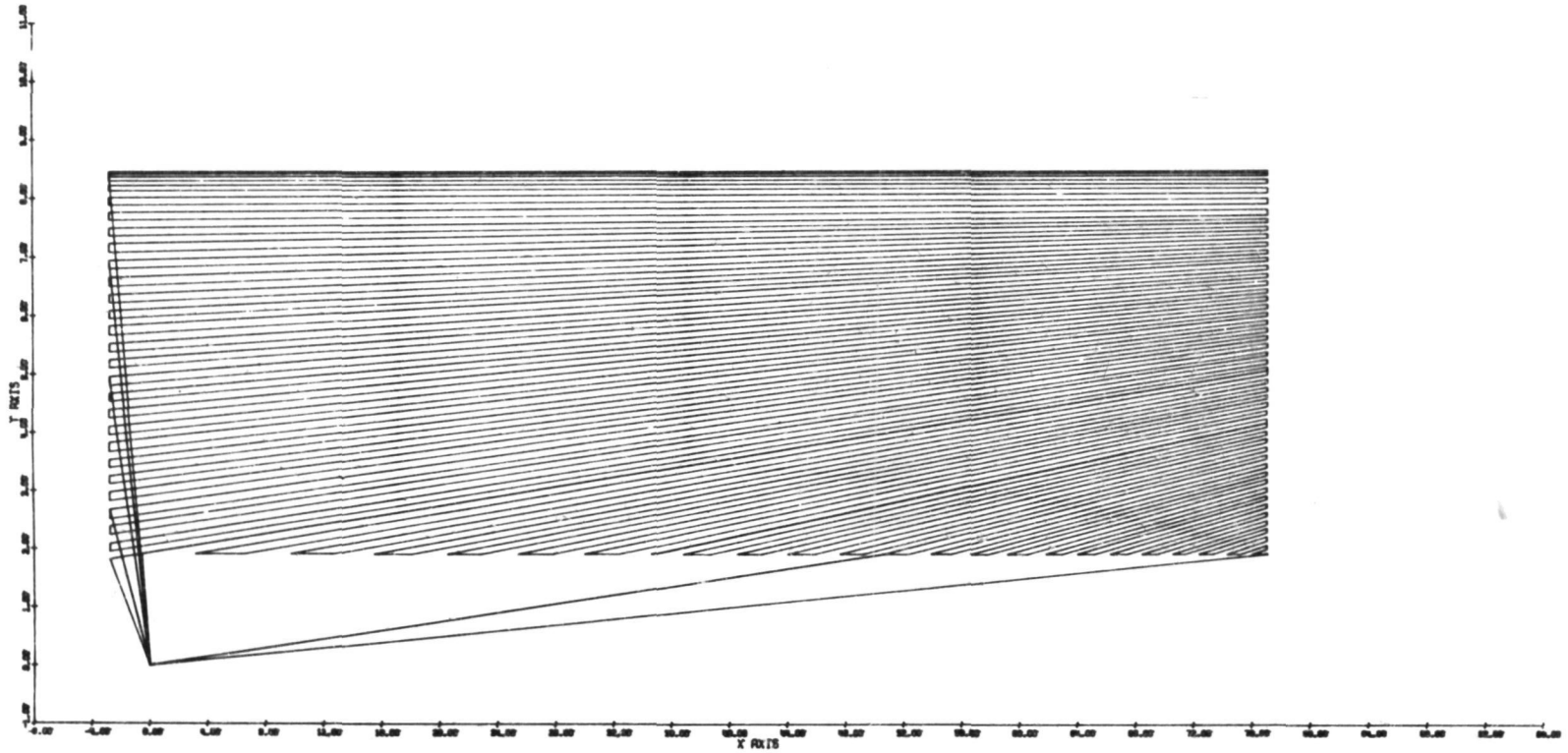


Figure 11.- Cutter path for N/C machining a form block.

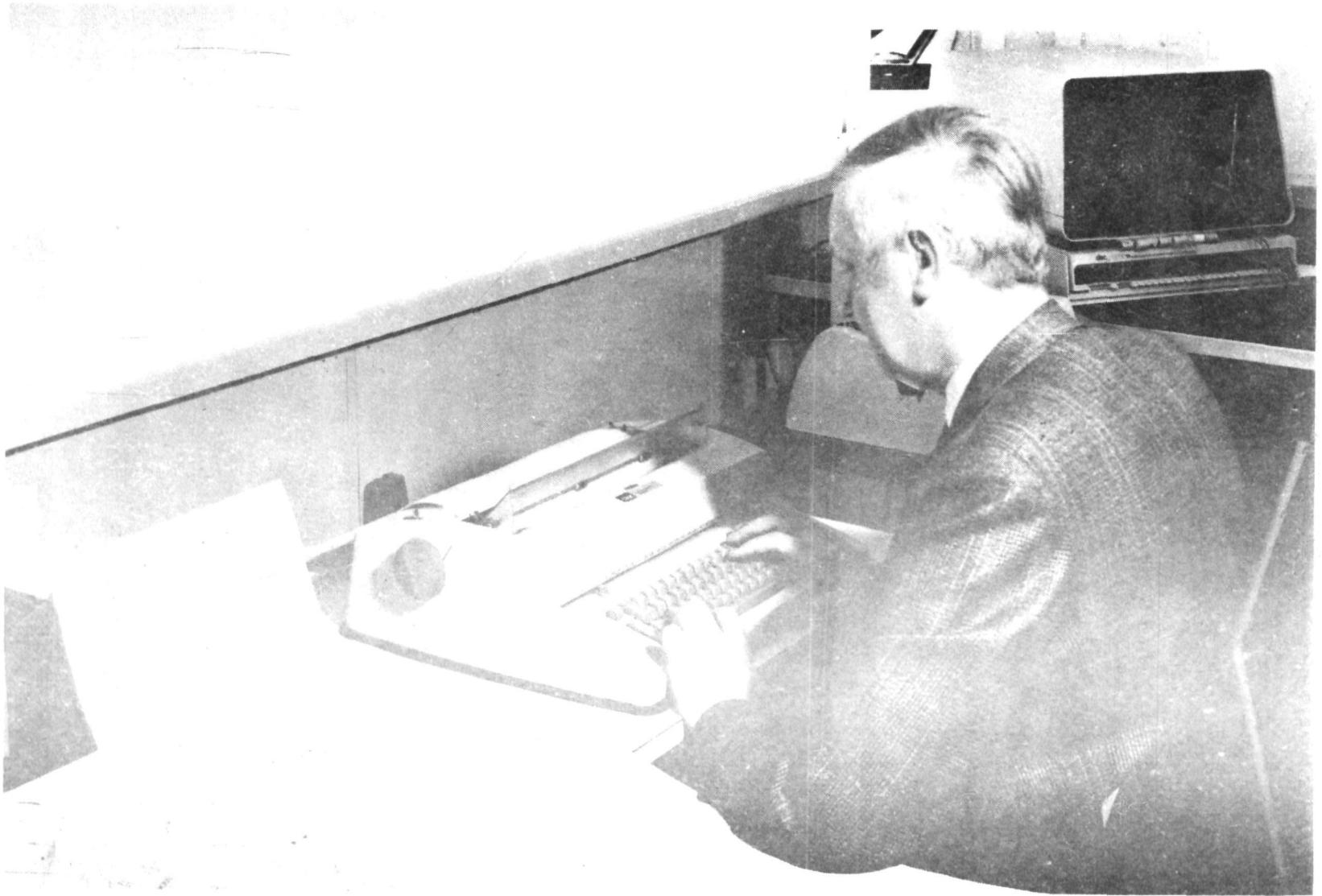
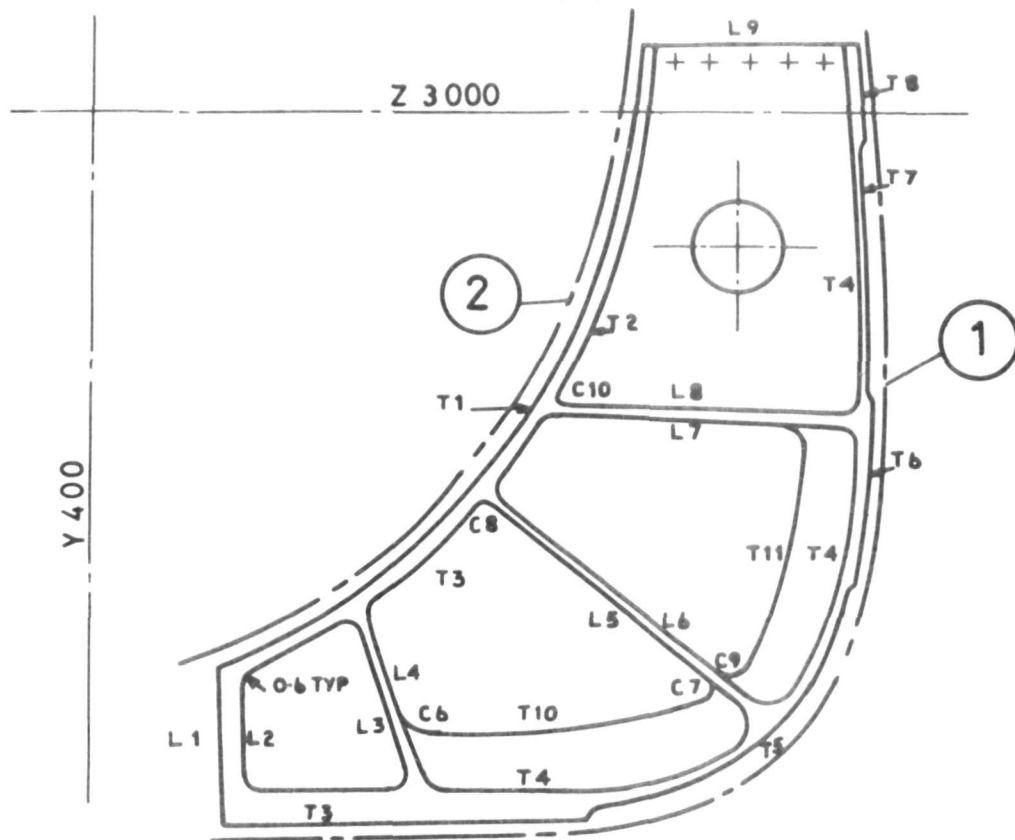


Figure 12.- Time sharing teletype terminal.



Figure 13.- Time sharing graphics terminal.



GEOM AO 8400E6	
NC FILE	
1	P/20/F000682/X4028
2	P/20/F000674/X4028
FILE NAME :- PANAMAST	

MACHINED FRAME

Figure 14.- Numerically lofted N/C machining drawing.

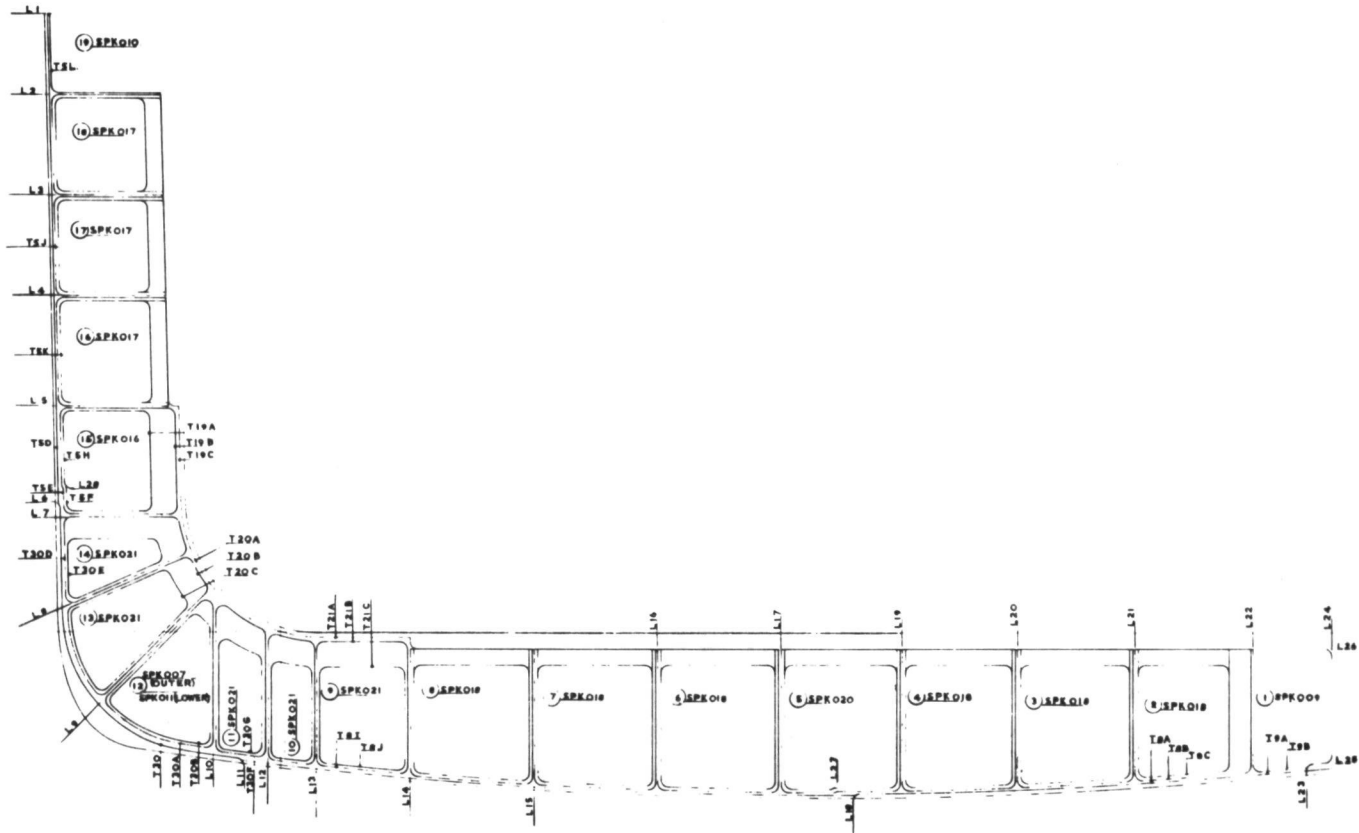


Figure 15.- Concorde intake frame: design produce a numerical definition and drawing which are passed to production.

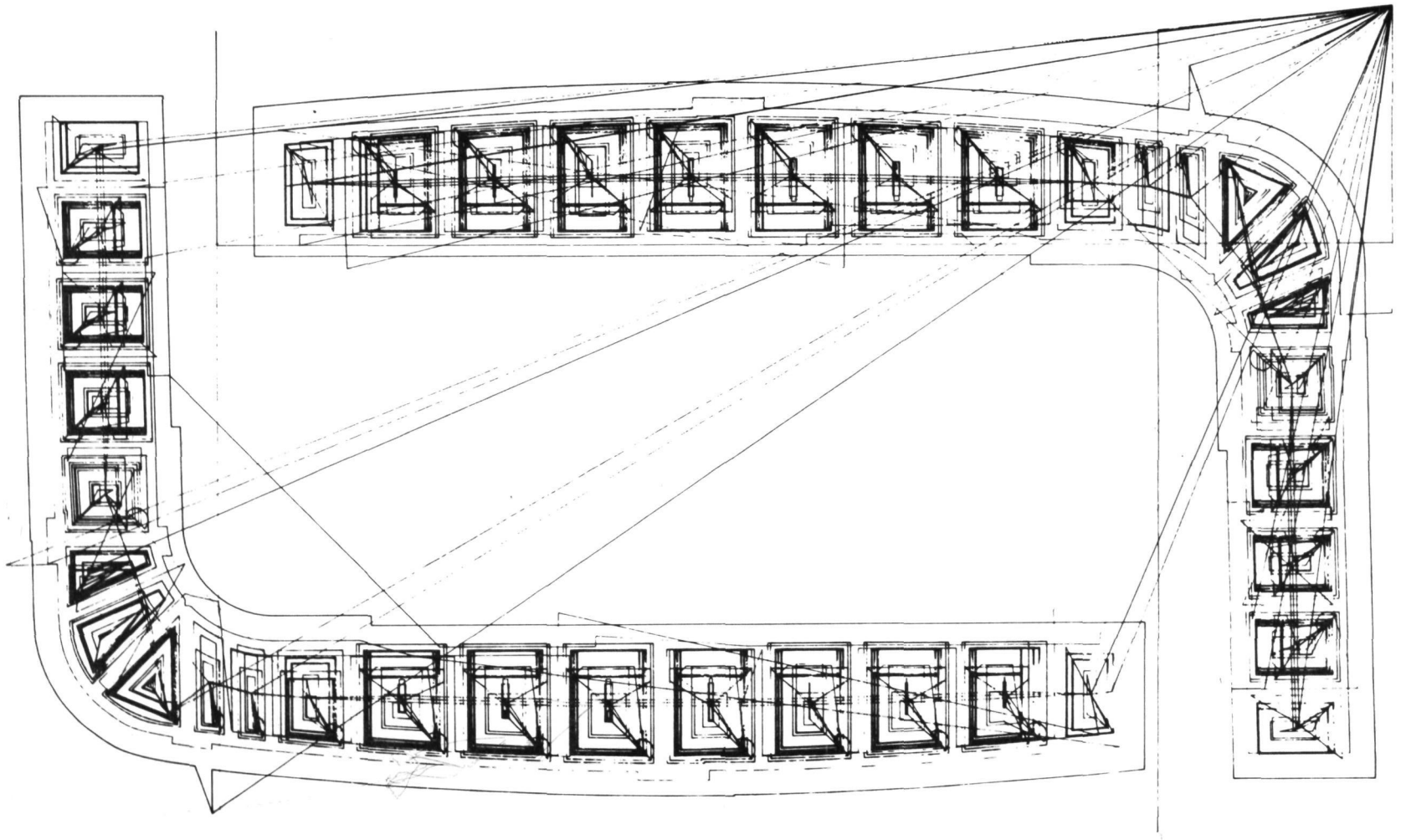


Figure 16.- Concorde intake frame: production plan the machine layout and cutter path.

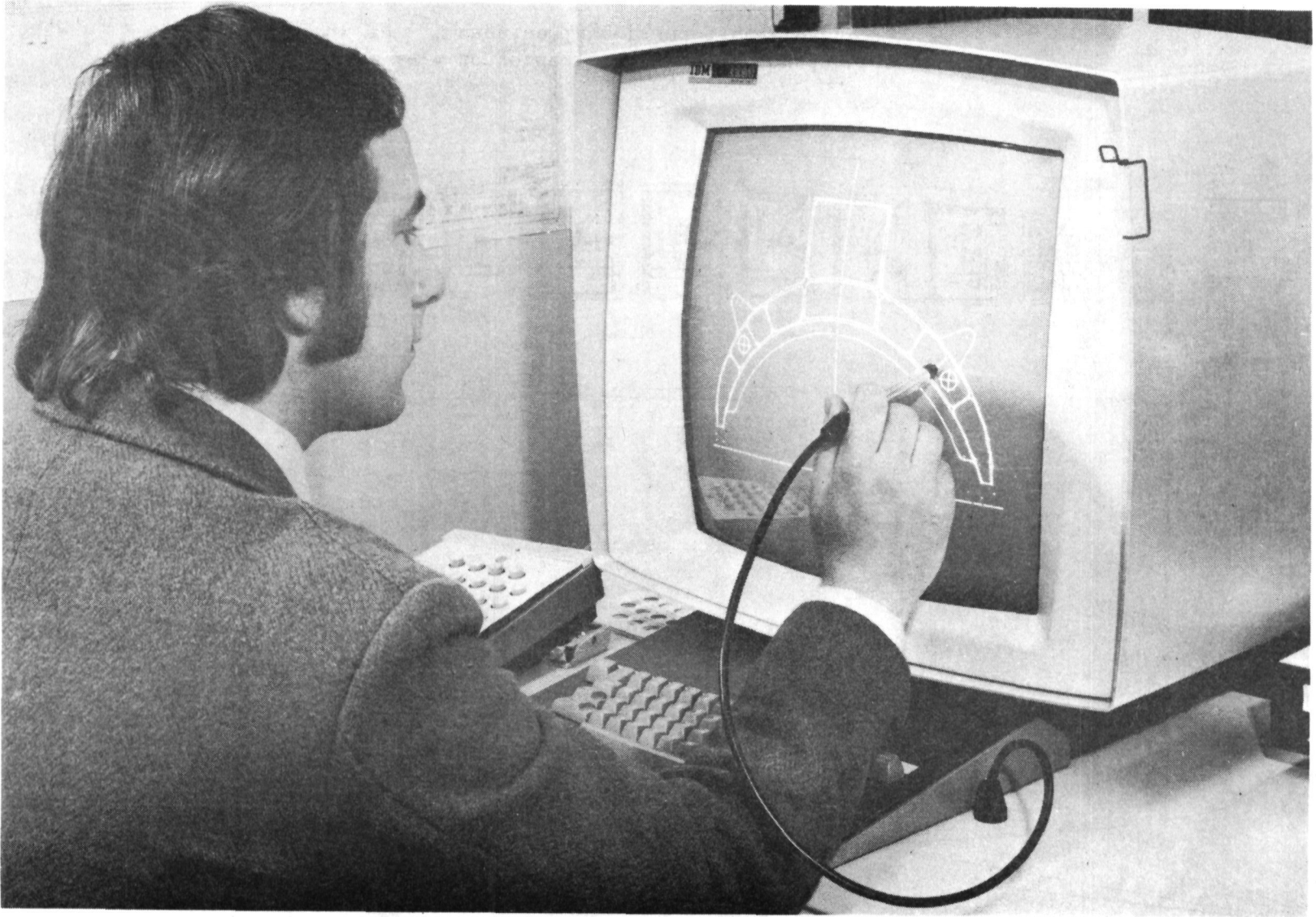


Figure 17.- Numerical lofting using interactive graphics.

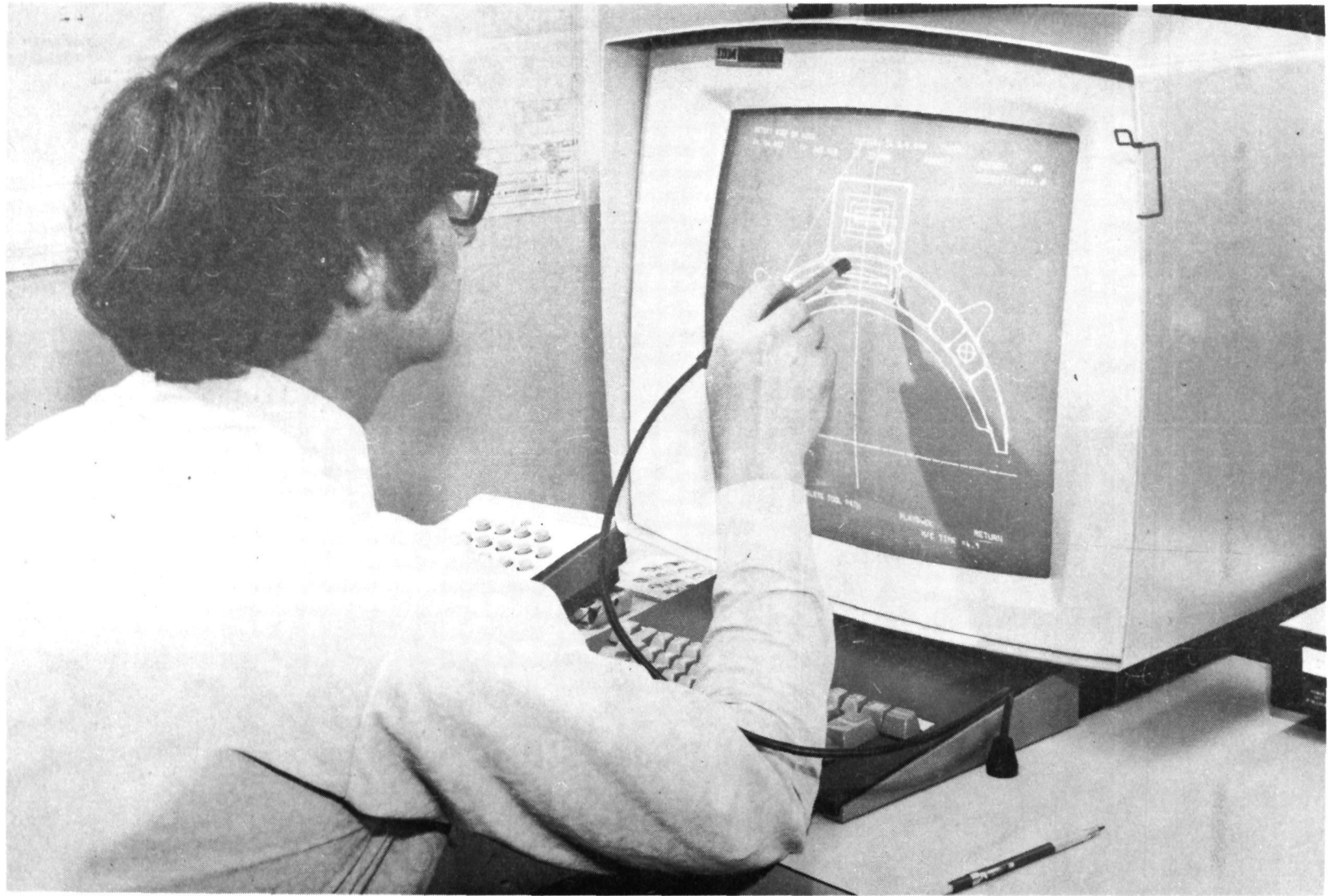
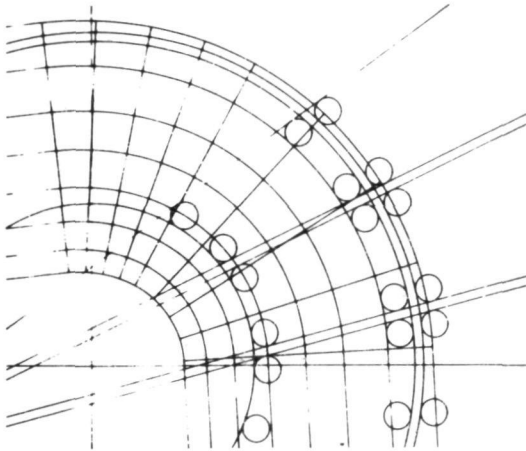


Figure 18.- Numerical machining using interactive graphics.

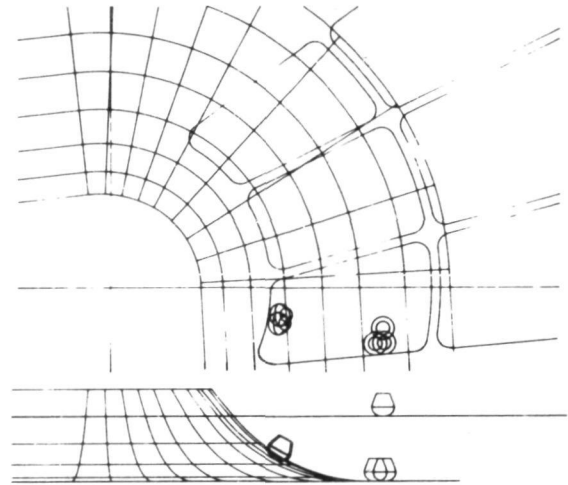


Figure 19.- Interactive APT using IBM 2250.

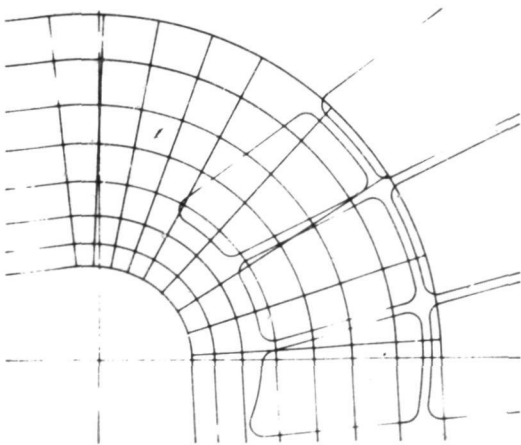
UNBOUNDED GEOMETRY



MACHINING A POCKET



BOUNDED GEOMETRY



CUTTERS

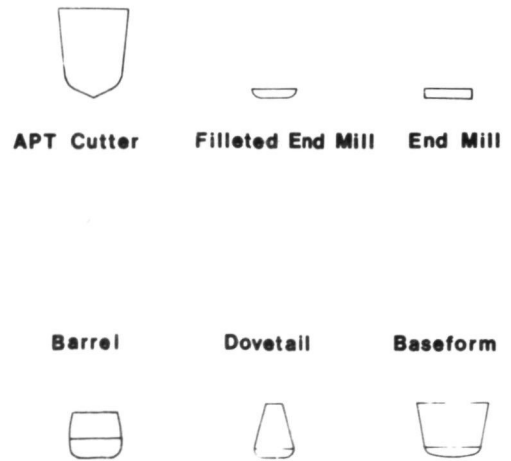
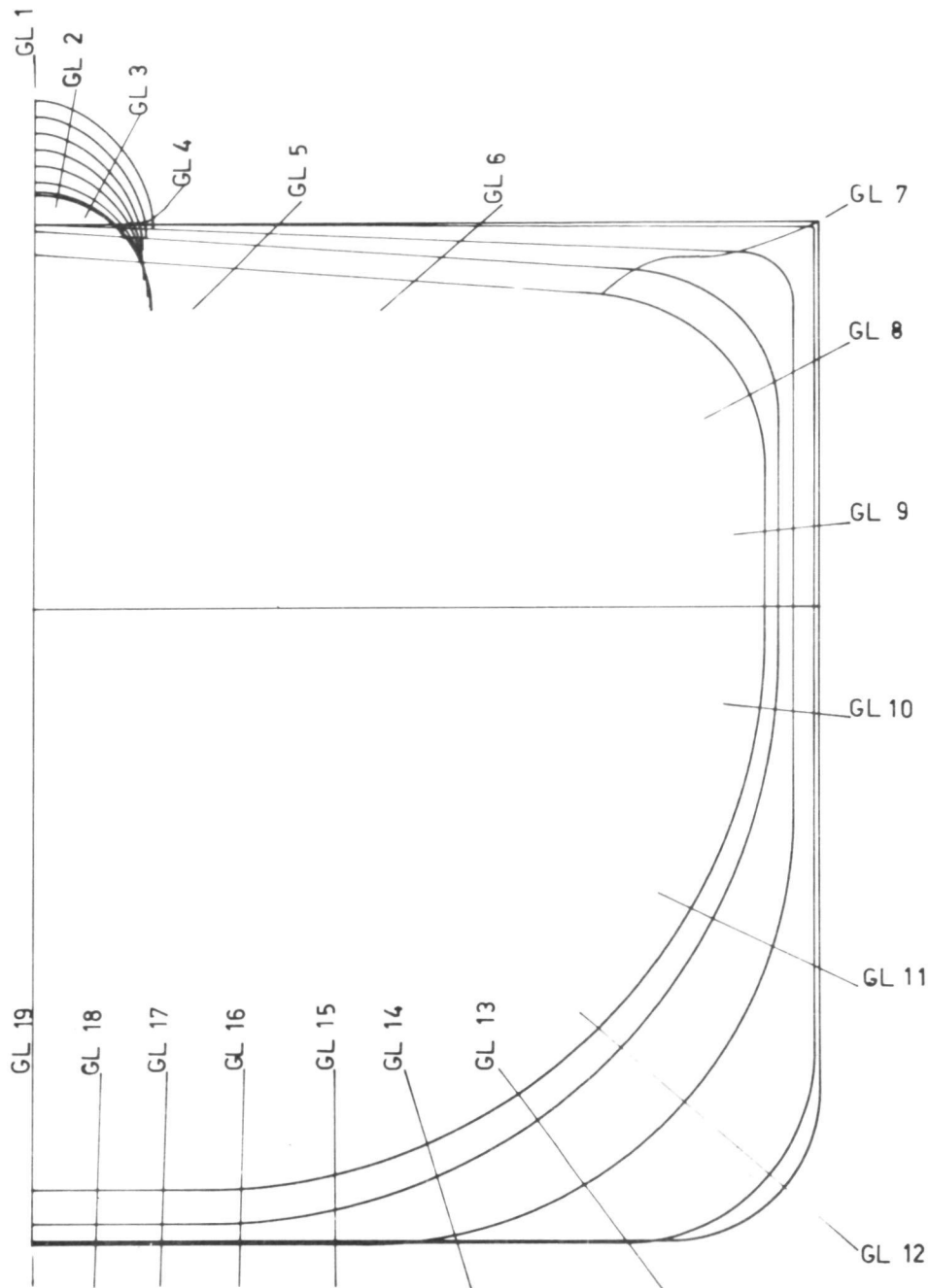


Figure 20.- Producing bounded geometry with interactive APT.



GRID LINES (GL...) DEFINED BY
 BOUNDED GEOMETRY PANEL POINTS
 FOUND WHERE GRID LINES INTERSECT
 THE NEXT OF SECTIONS.

Figure 21.- Panelling for aerodynamic calculations.

GRID LINES DEFINED BY BOUNDED GEOMETRY. STRUCTURAL ANALYSIS

NODES FOUND BY PROJECTING GRID INTERSECT POINTS ON TO SURFACES.

STRUCTURAL ANALYSIS ELEMENT DATA FOUND FROM NODE CONNECTIVITY DATA

e.g. GS5 INTERSECTS GR17 AT NODE 15

GS5 INTERSECTS GR 9 AT NODE 15

etc.

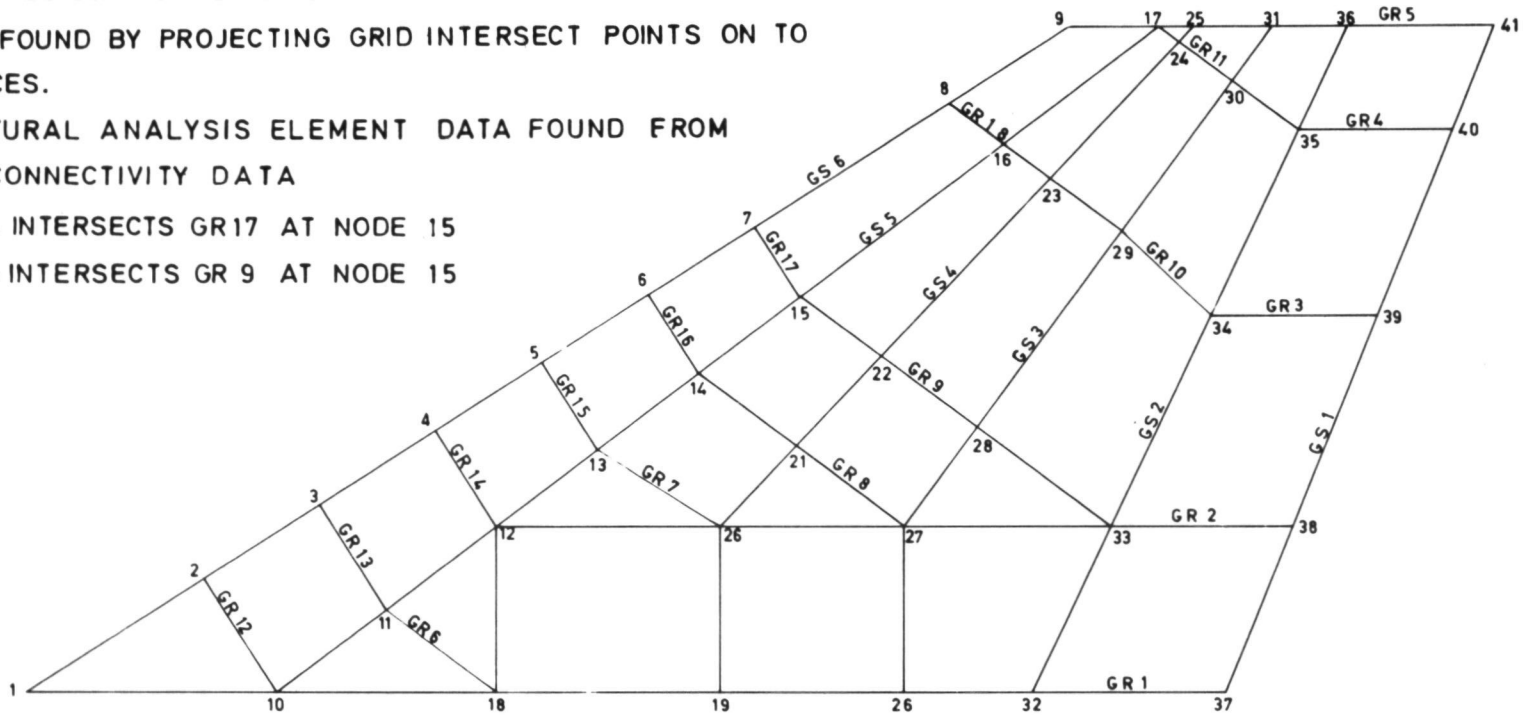


Figure 22.- Structural analysis grid.