associated hardware that controls the management of the cell as a whole, (ie. at a macro level). Functions that the CIMCELL would typically perform are the following :

1) Monitoring of the status of jobs on the shop floor.
2) Feedback to other systems on statistics such as time to manufacture, scrap rates, etc.
3) Coordination of jobs that require a sequence of processes on different machines.
4) Rescheduling of work on the various machines according to machine breakdowns, urgent job requests etc.

The development of algorithms and software to achieve the above is a very large task, and is out of the scope of this project. It is therefore proposed that the project entails the development of a data transfer system that incorporates sufficient flexibility to allow the inclusion of a CIMCELL "controller" at a later date.

3.4.2 The Data Transfer System

This system does not include any cell control functions, but completely encompasses the control of the data transfer from the database through the network and into the machines on the shop floor. In the interim, the cell control functions will be performed by the employees in the cell acting on data from existing MRP II systems. Figure 3.6 illustrates a conceptual idea of the configuration of the system.

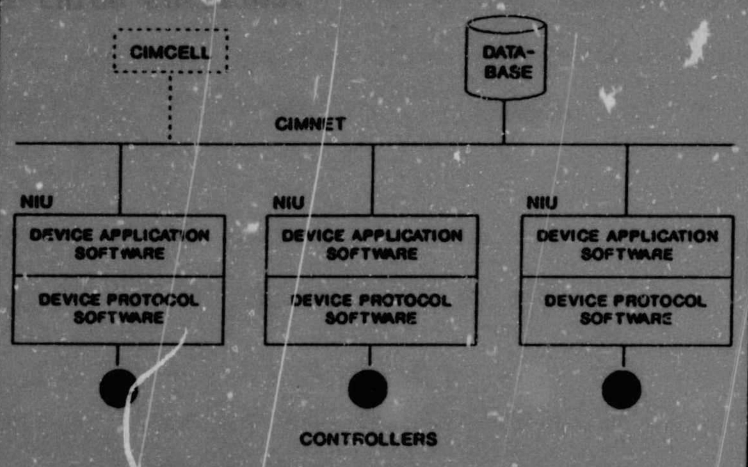

Fig 3.6 Complete Data Transfer System

The data transfer system is to incorporate the following :

1) NIU's are to be connected to each machine, incorporating Device Application software, (for interrogating the database), and Device Protocol software. (for feeding the data into each particular machine), - see Section 3.2.3 above.

2) A reliable, high speed network utilising fibre optic cabling due to the harsh environment.

3) A database that allows for the storage of all part programs that can be accessed by the NIU's when required.

This report explains the development and implementation of the above three entities.

4. OVERVIEW : BTR INTERFACE, DATABASE AND NETWORK SYSTEM

Section 2 of this report described the original CAD/CAM system used on the site. This section will describe the general alterations made to the system in order to facilitate the electronic transfer of CAD/CAM data to the NC and CNC machines on the shop floor. The system can be divided into three distinct components :

BTR INTERFACE : The software and hardware used to read NC programs into the NC machines.

BTR NETWORK : The system used to transfer electronic data to the location of the NC machines (shop floor) so that it can be read into the machines by the BTR Interface.

BTR DATABASE AND UTILITIES : The system used to manage and store the electronic output (NC programs) of the NC Programming department and make it available for transfer by the network.

Figure 4.1 shows how these three components interact to form the BTR system.

4.1 BTR Interface

The BTR Interface is described in detail in Sections 5 and 6. It is the hardware and software used to read the NC

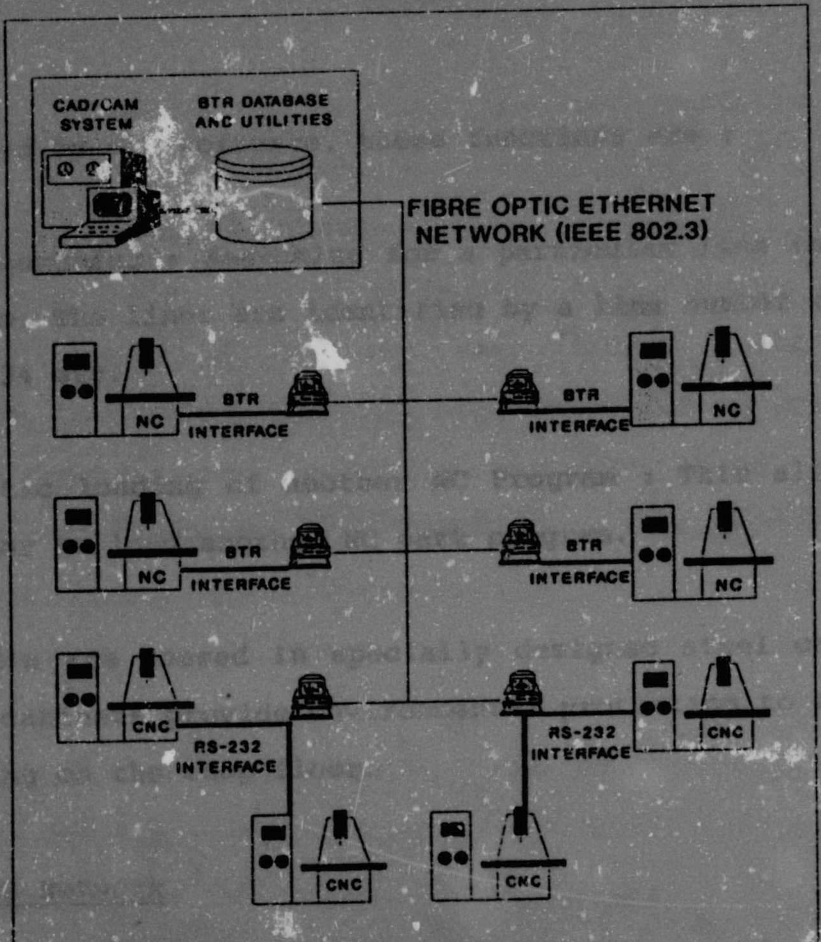

Fig 4.1 The BTR System Concept

programs into the various NC and CNC machines. A PC is connected to each NC and CNC machine on the shop floor. Specially written software residing on each PC controls the PC's standard Centronics output port or Serial RS-232C port. The software reads the NC program into the PC's memory and then systematically reads lines of the NC program into the NC or CNC machine as required.

Functions available to the machine operator that were not available on the original NC machine controllers are also provided by the software. these functions are :

Blocksearching : Searching for a particular line in the NC Program. The lines are identified by a line number eg. N105 or N2034 etc.

Automatic loading of another NC Program : This allows the operator to load another NC part program.

The PC's are housed in specially designed steel cabinets. These cabinets provide environmental protection to the PC's residing on the shop floor.

4.2 BTR Network

The BTR network is described in detail in Section 8. The network allows the NC program to be transferred electronically from the NC programming department to the NC and CNC machines on the shop floor.

4.3 BTR Database and Utilities

The BTR Database and Utilities are described in detail in Section 7. The BTR database stores all the completed NC programs on a hard disk in the NC Programming department. The programs are then accessed via the network by the BTR interface software on the shop floor.

Utilities to access the database are also available. These are used by the NC programmers to store completed programs in the database and to retrieve programs from the database. The utilities also provide automated facilities to copy NC programs from the database onto floppy disks. This procedure is invoked when the network is out of operation and NC programs are needed on the shop floor. The NC programs can then be manually transferred to the shop floor via floppy disc. Various other utilities are also available, and will be described in detail in Section 7.

Together the three components, the BTR Interface, BTR Network and the BTR Database and Utilities form an automated system of information transfer from the NC Programming department to the shop floor and into the NC and CNC machines.

5. BTR INTERFACE : NC MACHINES

As mentioned earlier, there are NC machines as well as CNC machines on the shop floor. The CNC machine controllers have "on-board" memory to store NC part programs and file management functions to manipulate them. The CNC machines also support industry standard RS-232C serial interfaces which allow information transfer to and from host computers. However, the older NC machines do not have "on-board" memory and can therefore only process one line of an NC part program at a time. The devices used to input the part programs into these NC machines, (paper tape readers, and more recently PC's), are therefore dedicated devices and monitor the status of the NC machine continually in order to input one line of the part program as needed. These NC machines do not support any input/output interfaces. The only interface available is the paper tape reader interface which is integrated into the electronics of the paper tape reader and the machine controller. This section describes the method of data transfer between the older NC machines and the PC's connected to them. In order to describe how this BTR Interface method of data transfer functions, it is necessary to describe how the original paper tape readers functioned.

5.1 Data Transfer using Paper Tape Readers

The paper tape used was an 8 track (25 mm wide) paper tape.

Characters were punched according to one of two industry standard character codes, EIA RS-244-A or ASCII (EIA RS-358). These codes and an example of the paper tape used appears in Appendix A. The NC machine controllers can be set to read either of the character codes. Figure 5.1 is a diagram of a typical paper tape reader. The paper tape is fed between a light source and bank of nine photoelectric cells by means of two sets of pinch rollers and two reels to contain the paper tape.

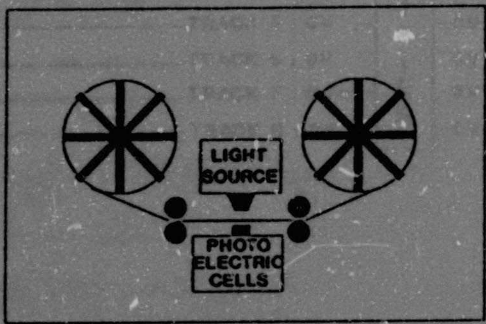

Fig 5.1 Diagram of a typical Paper Tape Reader

The paper tape is fed across the bank of photoelectric cells character by character. (A character on the paper tape is represented by a row of up to eight holes and a smaller sprocket hole, all alongside each other across the width of the tape - See Appendix A). Light emitted by the light source passes through the holes in the paper tape and energizes the photoelectric cells beneath each hole. The cells that are exposed to the light produce a voltage of approximately 0.5V. The individual voltages are then passed through an amplifier which amplifies the relevant energized circuits to 5V. This produces a row of parallel voltages of either 0V or 5V. Figure 5.2 below illustrates this process.

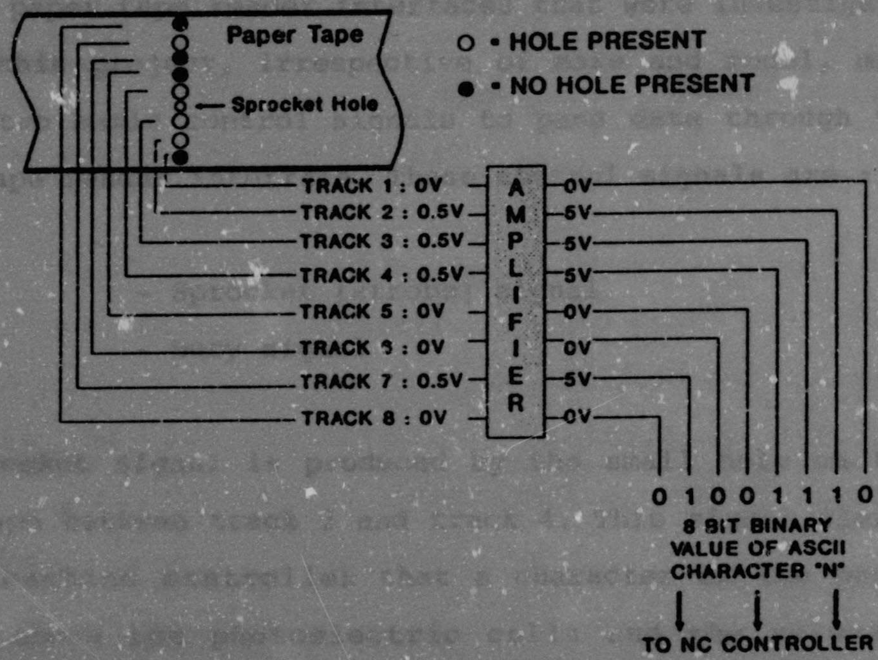

Fig 5.2 The Paper Tape Reading Process

As illustrated in Appendix A, each character has a unique representation of punched holes in paper tape. As explained above, these codes are transformed into eight parallel voltages, (TTL compatible, ie. either 0V or 5V), and can therefore be recognized by the NC machine controller and processed accordingly. The NC machine controllers continue to read characters until a carriage return or end-of-block character is encountered. The NC machine then performs the operation and upon completion, begins reading the next sequence of characters.

5.2 Paper Tape Reader Interface Control Signals

All the paper tape reader interfaces that were investigated during this project, irrespective of make and model, made use of two basic control signals to pass data through the paper tape reader interface. These control signals are :

- Sprocket (strobe) signal
- Busy signal

The sprocket signal is produced by the small hole on the paper tape between track 3 and track 4. This signal alerts the NC machine controller that a character on the paper tape is above the photoelectric cells and the relevant tracks, (of the eight parallel data tracks), have been energized and the character can now be accepted by the NC controller. The size of the sprocket holes on the paper tape is smaller than the data holes. This is to ensure that all the relevant data tracks have been energized before the sprocket signal is produced. As a character on the paper tape moves across the photoelectric cells, light passes through the leading edge of all the data holes and the relevant data tracks become energized. The character then continues to move across the photoelectric cells and light then passes through the smaller sprocket hole. This immediately produces the sprocket signal and the NC controller accepts the character described by the TTL level voltages on the eight data tracks. If the sprocket holes were as large as the data holes on the paper tape, light could pass through the leading edge of the sprocket hole before it passed through all the data holes, resulting in the NC controller accepting the character before all the relevant data tracks had been energized. This would cause corrupted data to be transferred.

The busy signal is produced by the NC controller. When this signal stops, it is an indication to the paper tape reader that the previous character has been accepted and processed and that the next character can be supplied. The data transfer sequence can be described by the following diagram :

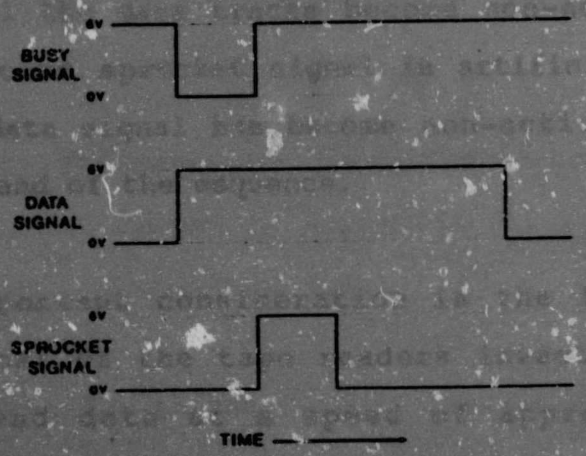

Fig 5.3 The Data Transfer Sequence

The data transfer sequence is as follows : Initially the busy signal is high (5V), indicating that the NC controller is processing the previous character. As the busy signal becomes low (0V), the tape reader energizes the relevant data tracks to 5V. A short while later the sprocket signal is energized to 5V. At this point the NC controller accepts the character and sets the busy signal to 5V while it processes the character. The sprocket signal is then set back to 0V and finally the data tracks are set back to 0V as the holes move off the photoelectric cells. The tape reader then waits until the busy signal is reset to 0V and the sequence begins again.

Figure 5.3 is a general description of the data transfer sequence. The paper tape reader interfaces differ between different makes and models of paper tape readers. For example, the data tracks are often inverted, ie active low, and the busy signals supplied by some NC controllers stay active until the data tracks become non-active. In some cases a second sprocket signal is artificially generated after the data signal has become non-active in order to signal the end of the sequence.

Another important consideration is the timing of the signals. Most of the tape readers investigated in this project read data at a speed of approximately 300 characters per second (cps). This is equivalent to 3.3 milliseconds per character. However, some of the readers