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A Survey of Telecommunications Services & Industry

Inputs Required by a National Public Switched Network

and for their Production

Potential for Regional Cooperation

A Report by TCIL for UNIDO

(~~Interim~~) FINAL

NOVEMBER, 1991

Telecommunications Consultants India Ltd.

(A Government of India Enterprise)

CHIRANJIV TOWER, 3RD FLOOR, 43, NEHRU PLACE,
NEW DELHI-110 019 INDIA

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A survey of the Telecommunication systems and industry
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CHAPTER 1

NATURE OF VARIOUS PUBLIC TELECOMMUNICATION NETWORKS & SERVICES CURRENTLY IN USE IN THE WORLD

1.1 Introduction

There is a wide variety of public telecommunication services. and the networks to provide them. currently in use in the world. However. there are four basic services of universal application and of particular interest to the developing countries These are:

- The plain old public telephone service (POTS)
- The public text or telex service
- The Facsimile (FAX) service
- The data service
- The message transfer service

1.2 The Plain old telephone service

1.2.1 The subscriber leases a telephone connection from the service provider and using the telephone instrument can establish a call to other subscribers almost anywhere in the world and speak to them at will. The service providers build up a hierarchical network of switching nodes and transmission systems with international linkages to permit this service. The network is known as the public switched telephone network (PSTN). The basic function of such networks is establisment. through the transmission systems and switching nodes. at the will and command of the subscriber. of a two wire physical or electronic circuit. from end to end. for each call. to any other subscriber any where in the world. for exchange of voice communication.

1.2.2 The POTS service is used not only by the business. industry and administrations but also by householders. The number of main telephone connections working from public networks in the world exceeds 500 million. an overwhelming majority of them however in the developed countries. The availabilty of telephone services in most of the developing countries has been very meagre.

1.2.3 Table 1.1 indicates the distribution of main telephone connections in different continents and a few of the most developed countries in them. as on 1.1.1988. The table shows that the availability of telephones per 100 inhabitants in Africa and Asia is very low. While the position in Asia appears better than in Africa. fact is that in Asia also most of the telephones are in Japan and Korea. Further. even in Americas. and Oceania most of the available telephones are in a few highly developed countries viz USA and Canada in Americas. and Australia and New Zealand in Oceania. Of late the rates of growth in the developing countries have shown an upward trend.

1.2 The telex service

1.2.1 The telex service is similar to the public telephone service except that the subscriber uses a teleprinter (or teletype as some call it) to exchange written text communication instead of the voice communication. They lease a teleprinter connection and the service provider builds a hierarchical telex network using transmission systems and switching nodes with international linkages. In this case also a two wire physical or electronic ciruit is built up from end to end with the difference that while for effective voice communication in a PSTN such a circuit should be capable of effective transmission of a band width of 4 KHz, a telex circuit uses a much smaller bandwidth usually about 120 to 240 Hz.

1.2.2 This service is used largely by business, industry and administrations who have to exchange large volumes of text communications. The service is however being supplanted by the data communication on one hand and facsimile service on the other. The number of main telex connections in the world is about 1.8 million. The growth of demand has been slowing down very significantly in recent years.

1.4 Facsimile service

1.4.1 In facsimile service any written text or sketches or even pictures can be transmitted and received using special facsimile machines in place of a telephone instrument. on a connection established on the PSTN network. Unlike the telex machine where the text has to be transmitted character by character as in typing and there are problems of language and script, in facsimile a true copy of the original document is reproduced at the receive end. It is faster and free from restrictions of script etc. The service is basically used on the existing PSTN networks.

1.4.2 This service is becoming very popular among business, industry and administrations.

1.5 Data service

1.5.1 With the advent of computers, it has become necessary to transmit and transfer large volumes of information, (text, numerals, sketches, and graphs etc) rapidly. This is done in digital form. A variety of data services have come up provided through a variety of networks. However the public data network services can generally be divided into following categories:

- Small and moderate speed data service upto 9600 bps on existing PSTN networks, with use of modems at the two ends.

- Medium speed data service upto 64 Kbps using either special data networks based on packet switching concepts or newly emerging Integrated services Digital Networks.

- High speed services of over 64 Kbps over special broadband networks being built in some of the developed countries.

1.5.2 <u>Data on PSTN:</u> The subscriber establishes a physical (or electronic circuit) through the PSTN and then exchanges digital data via the modems at the two ends. The connection can be used both for voice communication with the telephones and for data communication via the modems, using suitable change over arrangements. This is an economical method for exchange of data communications at moderate speeds, since it does not call for a seperate connection from the subscriber premises to the network and also does not call for establishing a seperate network. However when large volumes of data have to be exchanged and higher speeds are required, seperate networks become necessary.

1.5.3 <u>Data on seperate PSDN</u>: Seperate special networks based on Packet Switching Concepts have been established in many countries providing a whole range of speeds upto 64 Kbps. The start up costs tended to be high. Apart from a separate special network, separate subscriber lines are needed for access to the networks. They however became highly economical once the demand built up for higher speed data services. The development of integrated services digital networks (ISDN) holds promise of integrating the separate PSTN and PSDN into a cost effective integrated network.

1.5.4 <u>Data on ISDN:</u> Over the years digital technology has been applied both for transmission and switching. PSTN's with digital switches and trunks have become highly cost effective compared to analog ones. As a next step digitalisation of subscriber line to handle both voice and non voice services has been developed. Each subscriber line is suitably multiplexed at the subscriber terminal into two 64 Kbps voice/data channels and one 16 Kbps signalling/data channel. Use of common channel signalling and linkages between PSDN and PSTN permit the three channels to be used simultaneously, the first two for voice or data, or high speed facsimile and the third for signalling and data. This has brought about an integration of the voice and non voice networks and has eliminated the need for separate subscriber lines for PSTN and PSDN.

1.5.5 ISDN service has been introduced on various scales in most of the developed countries, basically by building up ISDN networks as an overlay on the existing PSTN and PSDN networks. Though the demand even in these countries has developed only slowly and the cost has been substantial, continuous developments are taking place. Eventually the establishment of ISDN networks may cost no more than setting up the PSTN. The demand could also be expected to grow not only in the developed countries but in also the developing countries. Keeping this in view, as an ample precaution against absolosence, PSTN networks are being expanded and renewed using the digital switches and transmission media with provision for upgradation to ISDN.

1.6 <u>The Message Transfer Service</u>

Telecommunication service basically started as a message transfer service in the form of public telegraphs. While eventually it was overtaken by the telephone service, it still has substantial utility as a form of business, administrative and personal communication. While seperate public telegraph networks have suffered a significant decline, need for a message service has been clearly recognized. The PSTN and ISDN networks are capable of supporting highly effective message transfer service by way of range, quality and cost of service. They can handle not only the traditional textual but also voice messages on a store and forward basis, through special computer based "user agents", "message stores" and "physical delivery access units". CCITT has made comprehensive recommendations on the subject. Electronic text and voice mail services have a significant potential and are of special interest to developing countries where public telegraph service is expected to continue to play an important role particularly in rural areas. They have the potential of integrating this service with the other communication services.

1.7 Observation

For the present, public switched telephone networks, based on fully digital switching and transmission systems, capable of supporting the plain old telephone, the facsimile, the data at moderate (upto 9600 bps), and in some cases medium (upto 64 Kbps) speeds, and the message transfer services, with potential for upgradation to ISDN, may be of the greatest interest to the developing countries.

The structure and the main components of such a network are discussed in somewhat greater detail in the text chapter.

Annexed:

TABLE 1.1 : DISTRIBUTION OF MAIN TELEPHONE LINES BETWEEN DIFFERENT CONTINENTS

Table 1.1 : Distribution of main telephone connections in different continents.

Table 1.1

Discribution of MAIN TELEPHONE LINES between different continents
As on 1st January 1988

Continent	No. of Main Lines	% growth over previous year	per 100 inhabitants
Africa	6,856,000	7.9	1.16
Americas*	163,520,000	4.1	23.70
USA	126,725,000	3.7	51.99
Canada	13,444,317	3.8	52.41
Asia*	88,763,000	6.5	3.10
Japan	49,247,000	3.4	40.34
Korea, R.	8,785,165	14.7	20.88
Europe	186,839,000	5.3	22.57
Oceania*	8,644,000	4.0	30.87
Australia	7,091,549	4.0	43.63
New Zealand	1,376,781	3.7	41.98
WORLD	454,622,000	5.[illegible]	9.1

[Source: Siemens International Telecom Statistics:1989]

* In Americas out of about 163 million main lines nearly 120 million were accounted for by USA, and about 13 million by Canada.

* In Asia out of about 89 million main lines over 49 million were accounted for by Japan, and another about 9 million by Republic of Korea.

* In Oceania out of about 8.6 million main lines, about 7 million were accounted for by Australia and about 1.4 million by New Zealand.

Thus in these three continents also, if the figures for these highly developed countries are taken out,the availability of main lines, in absolute numbers as well as per 100 inhabitants is at present extremely low.

Chapter 2

BASIC STRUCTURE AND MAJOR COMPONENTS OF NATIONAL PUBLIC SWITCHED TELEPHONE NETWORKS

2.1 Introduction

2.1.1 National public switched telephone networks consist of a hierarchical system of switching nodes or exchanges interconnected by groups of trunks or junctions over suitable transmission media. Appropriate user terminals at customer premises or public places are connected to this network over subscriber lines. Under the aegis of the International Telecommunication Union and specially its Committee concerned with Telephony and Telegraphy, the CCITT, there has been considerable standardization in regard to the structure, the component systems and the interfaces. The Public Switched Telephone networks designed, constructed and operated in accordance with agreed CCITT recommendations will give highly satisfactory world wide telephone, facsimile and moderate speed data transmission service.

2.1.2 The switching nodes and transmission media have evolved through a variety of analogue systems to the present fully digital ones. A combination of the digital switching and the digital transmission systems provides the most reliable and cost effective networks and has been assumed in all further consideration.

2.2 Network components and structure

Fig. 2.1 illustrates the basic concept and structure of a national hierarchical Public switched telephone network. The network is essentially designed to establish, on demand, a physical circuit between the calling and called subscribers, to enable the transmission of communication: voice, facsimile and moderate speed data, with reasonable level of privacy, and to breakdown the circuit when no more required. It consists of following main functional components:

2.2.1 Subscriber apparatus

2.2.1.1 Indicated by a telephone instrument symbol in fig 2.1, it is the apparatus used by the subscriber to signal his requirements to the network and communicate with the called party. It may consist of a telephone instrument, a facsimile machine or a modem interfacing between the subscriber line and a data terminal e.g. a personal computer.

2.2.1.2 The basic function of the apparatus is to transmit and receive signals to indicate the connection requirements to the network and to convert the voice, or optical scan of a document or the digital data into electrical signals capable of transmission on electrical circuits and vise versa.

2.2.1.3 Private Branch Exchange (PBX's) : While strictly not a subscriber apparatus as defined above, PBX's are an important piece of equipment at the subscriber premises particularly for the institutional subscribers, business or otherwise. They meet the need for considerable internal and external communication in such establishments. They are basically a switching node with certain special features and have developed in parallel with public switching nodes. Digital PBX's have now become universal and are rapidly replacing the existing installations of earlier equipment. Besides handling the traditional internal and external communication, they are able to support a whole range of voice and non-voice services and have become an important tool in office automation.

2.2.2 **The subscriber line.**

2.2.2.1 This consists of an exclusive, dedicated, 2 or 4 wire physical or equivalent circuit connecting the subscriber apparatus to the first switching node known as the subscriber exchange (SE in figure 1) or to a remote switching unit (RSU) which is a part of the subscriber exchange, located remotely.

2.2.2.2 The function of the line is to provide a path for the signalling and communication currents between the subscriber apparatus and the network. It may be provided physically on a pair of wires or on an equivalent circuit derived through multiplexing on a pair of metallic conductors, symmetrical or coaxial, on optical fibres or on a radio system. As a physical pair it may consist of an open wire line, or a twisted insulated pair of conductors in a cable carrying many such pairs. The cable may be laid underground directly buried or pulled in a duct or may be slung aerially on poles.

2.2.2.3 While the continuously rising costs, problems of reliability, the electromagnetic interference and the aesthetics have made the open wire lines totally obsolete, in general, physical copper pairs in cables continue to provide a highly cost effective alternative, for subscriber lines for fixed installations, particularly in urban areas of high density. When using such physical pairs of wires, good transmission and signaling require a low resistance, usually a maximum of 1000 ohms, and a high insulation, usually a minimum of about 20 Kohms. The line has to be protected from deterioration due to adverse weather conditions etc. It also needs protection from lightning strikes and contact with power lines, and a reasonable freedom from electro-magnetic & electro-static interference from other circuits, which could give rise to noise and/or cross-talk. These requirements are met by choice of the conductor gauge, insulating materials & practices, moisture barriers, electrostatic balancing and twist of different pairs in different lays etc.

2.2.2.4 In many situations particularly in rural and remote areas of low density, radio based systems, terrestrial or via the satellites, particularly the demand assignment multiple access systems, provide a more cost effective and reliable alternative. For the mobile service they are the only feasible alternative. Considerable experimental and development work is also in progress for the use of optical fibres for subscriber lines.

2.2.3 **Subscriber exchange** (shown as a circle marked SE in figure 2.1.)

2.2.3.1 Every subscriber's line is connected to a subscriber exchange which is known as his parent exchange. All outgoing and incoming calls from and to the subscriber are routed through this exchange. The subscriber exchange has a small element exclusively dedicated to each subscriber line, which provides the interface to the rest of the network. The main functions of a subscriber exchange are:

a) Continuously monitor the subscriber line, promptly detect the calling signal whenever the subscriber wants to originate a call and acknowledge the signal (by transmitting a distinctive tone known as dial tone).

b) Accept from the subscriber, signals indicating the called line number. These used to be in the form of decadic dial pulses but of late, are, more and more frequently, in the form of dual tone multi-frequency signals. These are generated using electronic networks by operating appropriate switches by pressing alternative push buttons.

c) Determine the most appropriate direct route through the network to establish a through connection between the called and calling subscribers and monitor its establishment. In case of any congestion enroute, check successive alternate routes till a final choice or back-bone route is reached. If there is congestion even on this route, transmit to calling subscriber a route congestion signal, either a distinctive tone or a recorded announcement.

d) In case of an incoming call, test whether the called subscriber is free or engaged on another call. If engaged, indicate this to the calling subscriber's exchange which then transmits a called subscriber engaged signal to the calling subscriber. If the called subscriber is free, transmit a calling signal which is a distinctive ringing current and results in a bell or buzzer sounding at the called subscriber's apparatus. A tone is also fed back to the calling subscriber indicating that the called subscriber is free and is being rung.

e) When the called subscriber answers by lifting his hand set which automatically gives a signal to his exchange, establish the through connection for the calling and called subscribers to communicate.

f) The calling subscriber's exchange notes the call particulars suitably and monitors the call. When the calling subscriber signals the end of call by replacing his hand set, it initiates release of the connection through all the nodes, and also notes down the duration of the call. It may store full details of the call,that is, calling number, called number, time of commencement and completion of the call; or it may record only the chargeable call units to to the account of the calling subscriber, depending on the system of billing i.e. detailed or bulk.

g) The calls between subscribers connected to the same exchange are handled entirely within the exchange. Calls between two subscribers connected to two different exchanges in the same local or urban network may be routed directly between the two exchanges or via a tandem (shown in fig 2.1 by a rectangle marked TDM). The calls between two subscribers connected to two exchanges not forming part of the same local network will be routed via one or more transit exchanges and the connecting trunks between them.

2.2.3.2 The number and location of the subscriber exchanges is determined by techno-economic considerations, such that the overall investment and operating costs of the local network consisting of the subscriber lines, the subscriber exchanges, the tandem exchanges and the junctions between all these exchanges is the least.

2.2.3.3 Mention has been made of Remote switching units. These are parts of the subscriber exchange located remotely and used to concentrate traffic from a number of subscribers and carried to the main exchange on a comparatively smaller number of junctions. They are used, to effectively reduce the average length of the subscriber line and thus its cost. On the other hand they add to the network cost by way of junctions and separate infrastructure: building, power, air conditioning etc. The number and location of Remote switching Units is decided so as to ensure tnat the overall cost of subscriber cables plus the additional cost of providing the RSU's is optimised. With the economies possible in provision of junctions through various digital media such units have become highly cost effective to serve fringe areas of low density in large urban centres and for serving a cluster of a number of small townships each with its own remote switching unit controlled by a centrally located full subscriber exchange.

2.2.4 **Tandem Exchange** indicated by a rectangle marked TDM in fig 2.1

2.2.4.1 Tandem exchange accumulates small outgoing traffic from a number of exchanges and distributes incoming traffic from a number of exchanges into them. The basic justification for tandem exchanges arises from the fact that groups of small number of junctions are highly inefficient. Merging small volumes of traffic to and from a number of exchanges helps build up larger more efficient groups of junctions. The number and location of tandems is decided by balancing the increase in investment and operating costs because of introduction of another switching stage and their reduction by substituting a large number of small groups of junctions, to a smaller number of larger groups of more efficient junctions, thus ensuring the most economical configuration.

2.2.5 **Transit (Trunk) exchange**: indicated in fig. 2.1 by a triangle and a square marked 1T and 2T

2.2.5.1 Trunk transit is an exchange which basically handles transit traffic from and to other exchanges, subscriber and/or other transit. The economic justification for such exchanges is the same as for the tandem exchange, except that they handle longer distance traffic. Depending on size and topography of the country,there may be a number of levels of transit exchanges in the hierarchy.

2.2.5.2 The lowest or first level of transit exchanges are called primary transits. They switch traffic between subscriber exchanges or between subscriber and second level transit exchanges also known as secondary transit exchanges. In very large networks there may be even higher levels of transit exchanges known as tertiaries.

2.2.5.3 The basic function of transit exchanges is to transit traffic between other exchanges. For this purpose these exchanges receive signals indicating the called number, find the most appropriate route to the called subscriber exchange, either direct or through other transit exchanges and exchange further signals about the progress of the call. Eventually a through communication channel is established from the calling subscriber, through his parent subscriber exchange, through one or more transit exchanges, finally to the called subscriber through his parent subscriber exchange.

2.2.5.4 In addition to the basic transit function, 1st level or primary transit exchanges are sometimes also entrusted the task of determining and transmitting to subscriber exchanges the call charge information or centrally recording the detailed billing information for a number of small subscriber exchanges, whose size may not justify the cost of these features. In these cases the control and monitoring of the long distance or trunk calls is transferred from subscriber exchange to the primary transit exchange. These exchanges are therefore also sometimes called trunk automatic exchanges.

2.2.5.5 With the adoption of stored programme fully digital technology and functional modularity, a large part of the hardware as well as software of subscriber, tandem and trunk transit exchanges has become identical. Different exchanges can be suitably engineered with the same basic building blocks.with suitable additional modules to serve the special function for particular application. Further, the same exchange can also be configured to work partly as a subscriber exchange & partly as a tandem and / or transit exchange to route traffic from and to other exchanges permitting significant economies in building up networks. Such exchanges are appropriately called Integrated Local cum Transit Exchanges (ILT's).

2.2.5.6 The number and levels of transit exchanges in a national network is decided on the one hand by the country's size, the densities of population, telephones, and traffic in different regions, and on the other by comparative costs of switching and transmission systems. Till recently the per channel cost of transmission systems compared to the per termination cost of switching equipment, was significantly higher, particularly in case of very long trunks. In the larger countries therefore, the national networks had been configured with 3 or sometimes even four levels of trunk transit exchanges. With digitalization of transmission systems, and in particular advent of optical fibre and satellite transmission systems, per channel cost of transmission systems has come down considerably and is becoming fairly independent of distance. The general trend now is to configure national networks with only two levels of trunk transit exchanges namely the primary and the secondary, as shown in Fig 2.1.

2.2.5.7 Besides the functions of establishing through circuits for communication, exchanging signals for that purpose, and keeping an account of the usage by the subscribers for billing, the subscriber, tandem and trunk transit exchanges have also elaborate facilities for traffic measurement, for supervision of calls and for maintenance and operation. The facilities include continuous monitoring of the various pieces of equipment, observing any failures and identifying the faulty module with suitable alarms and print outs. They also include the monitoring and testing of the conditions of the subscriber lines and inter-exchange trunks.

2.2.6 <u>International Gateway Exchange</u> (Indicated by a star marked IG in fig 2.1)

2.2.6.1 The international gateway exchange is another trunk transit exchange, with the speciality that all international traffic from and to subscribers in other countries is routed via the international gateway. Apart from the normal function of providing a through circuit between the calling and called subscribers in the two countries, the gateway exchanges have facilities to record elaborate data and statistics for calls to and from different countries, to help settle accounts between the administrations of different countries and any international transit exchanges enroute.

2.2.6.2 The number of international gateway exchanges is generally determined by the size of the country. Most countries except the very large ones, or with very high international traffic, are able to do with only one.

2.2.7 **<u>Operator Services Switchboards</u>** (Indicated by a symbol of a desk marked OSS)

2.2.7.1 The trend basically is towards a fully automatic operation of the network under the control of the subscribers. However, occasionally operator assistance becomes inevitable, e.g. for failure reporting, directory inquiry, reverse call charging, and emergency services etc. It is usual to provide for subscriber access to operators by dialing short standard codes. The access circuits are terminated on suitable switchboards with a variety of facilities to provide the necessary assistance. The operators have special access to the network and computerized information data banks, test facilities etc.

2.2.7.2 The number and location of operator services switchboard centres in the network is decided on techno-economic considerations, and is essentially a judicious balance between economies arising from centralization of manpower and common facilities and the additional costs of switching and transmission in switching all operator assistance traffic to a central point.

2.2.8 **<u>Inter-node or inter-exchange trunks</u>**

2.2.8.1 Various exchanges (or switching nodes) are suitably connected to other exchanges by groups of circuits called trunks. In modern networks these are invariably digital four wire circuits derived through digital multiplexing on a wide variety of transmission media, symmetrical pair cables, coaxial pair cables, optical fibre cables, and radio relay systems, terrestrial and satellite based, working in different frequency ranges

2.2.8.2 The provision of trunks between any two exchanges is decided by the community of interest, i.e. the anticipated traffic between them. However every subscriber exchange is essentially connected to its parent primary trunk transit exchange, every primary transit exchange is essentially connected to its parent secondary trunk transit exchange and every secondary trunk transit exchange is connected to every other secondary transit exchange in a two level transit hierarchy. These essential trunks are known as the last choice or back-bone routes. In addition to these, depending on the community of interest and traffic anticipation, direct routes are provided between certain subscriber exchanges, from subscriber exchanges to primary trunk transit exchanges other than their parent, and similarly from primary transit exchanges to secondary transit exchanges other than their parent. Such trunks are known as high usage trunks and are provided only if the traffic justifies a sufficiently large high efficiency trunk group.

2.2.9 **A practical network**

2.2.9.1 Fig 2.1 basically illustrates the concept of a hierarchical PSTN. It shows only two subscriber exchanges and only two each of the primary and secondary transit exchanges. It shows only one RSU from each of the subscriber exchanges and only one subscriber from each subscriber exchange and RSU. In practice a subscriber exchange may serve from a few to many thousands of subscribers. Similarly a RSU may also serve from a few to a few thousand subscribers and there may be a number of RSU's parented to a subscriber exchange. The network may have from a few to thousands of subscriber exchanges. Each primary transit exchange will parent many subscriber exchanges and in turn a secondary exchange will parent many primary exchanges. There may be many secondary exchanges. In a very large network there might be even higher level (i.e. tertiary) exchanges.

2.2.9.2 Fig 2.2 gives a typical distribution and location of various levels of switching nodes in an imaginary small country with five secondary level transit exchanges. Each of these secondary level transit exchangeshas a co-located primary and even a subscriber exchange. One of them marked A, has also co-located an international gateway exchange.

Each secondary exchange A, B, C, D, and E, has parented to it a number of primary exchanges and in turn each primary has a number of subscriber exchanges parented to it.

Every secondary is connected to every other secondary and to its dependent primary exchanges by the backbone trunks. Every subscriber exchange is connected to its primary. In addition some of the exchanges parented to the same or an adjacent primary exchange have also direct trunks.

2.3 **Network plans**

For effective and efficient operation, the design of network calls for consideration of many aspects. The service provider has to ensure that an access connection is provided to any prospective subscriber within a reasonable time after . quest. Further the network has to be so designed as to permit establishment, on demand, of a through circuit, physical or suitably derived on various alternative transmission systems or a combination thereof, between the calling and the called subscriber apparatus, from any where to any where, to enable transmission of communication - voice, facsimile, and moderate speed data, with a reasonable level pf privacy; and to breakdown the circuit when no more required. This has to be achieved reliably and at minimum cost. Some of the issues to be considered are:

a) A realistic forecast over a reasonable period of likely subscribers, their location and the traffic between them.

b) A numbering plan, such that each subscriber has an international unique number on which he can be called.

c) Selection of optimum number and locations for subscriber exchanges and a subscriber line network plan to ensure an economic access from all prospective subscribers to the network.

d) A switching and routing plan, to enable establishment of through connections from any subscriber to any other subscriber economically and reliably with adequate redundancy to take care of any failures, or temporary route congestions.

e) A plan for internode and subscriber to network signalling.

f) A transmission plan to ensure high quality of error free transmission from end to end, irrespective of length of the connection and number of intervening nodes.

g) A charging plan i.e. method of charging for use of network, according to length of connection, duration, time of day etc. and the system of recording i.e. by periodic pulse metering for bulk billing or detailed accounting with details of each connection established.

h) Choice of appropriate technologies and products for subscriber apparatus, subscriber lines, switching nodes and transmission trunks to ensure economy with reliability and maintainability in different types of situations like subscriber density, terrain, distances etc.

i) Dimensioning the nodes, trunk groups etc. to handle the anticipated traffic with a target grade of service.

j) Choice of sources of power particularly in rural and remote areas.

k) Plans for maintenance and operation of equipment and network.

All these and many other issues besides the direct cost of equipment and materials have to be taken into consideration to achieve overall economies.

These plans are an essential input for proper planning, configuring and operating the network. While not directly affecting the manufacture of hardware, they are required to engineer the functional modules in the switching nodes and transmission media, and the software. Eventually they affect the network costs, future expandability, and introduction of new evolving services without major cost penalties

These plans are thus of vital importance for the successful operation a network. Their more detailed treatment is, however, outside the scope of this survey.

2.4 Major equipment going into the building up of a PST network

The above is basically a very brief and elemetary description of the major functional components of a PST network. Each of these functional components is built up using a very large variety of products. It is impossible to list all of them in any brief report. However a brief list of products that go to build up the network is given in Table 2.3.

2.5 Average network Cost per line

The end product of the network can be cosidered a subscriber connection at the subscriber premises which can be used by him for communication with any other subscriber any where in the world. Such connections are variously referred to as main line. main connection or direct exchange line. The average investment cost of the network per main connection or direct exchange line is quite substantial and has been one of the inhibiting factors in adequate growth of Telecommunication networks in developing countries. In the next chapter the average investment cost per line for a national public switched telephone network and its breakdown to different components is discussed briefly with a view to gain insights into the possibilities its reduction.

Annexed:

Figures

2.1: Conceptual block diagram of a hierarchical PSTN

2.2: Typical model network topology for a small country

Table

2.3: A brief indicative list of systems and products going into a PSTN

CONCEPT OF HIERACHICAL P.S.T.N.

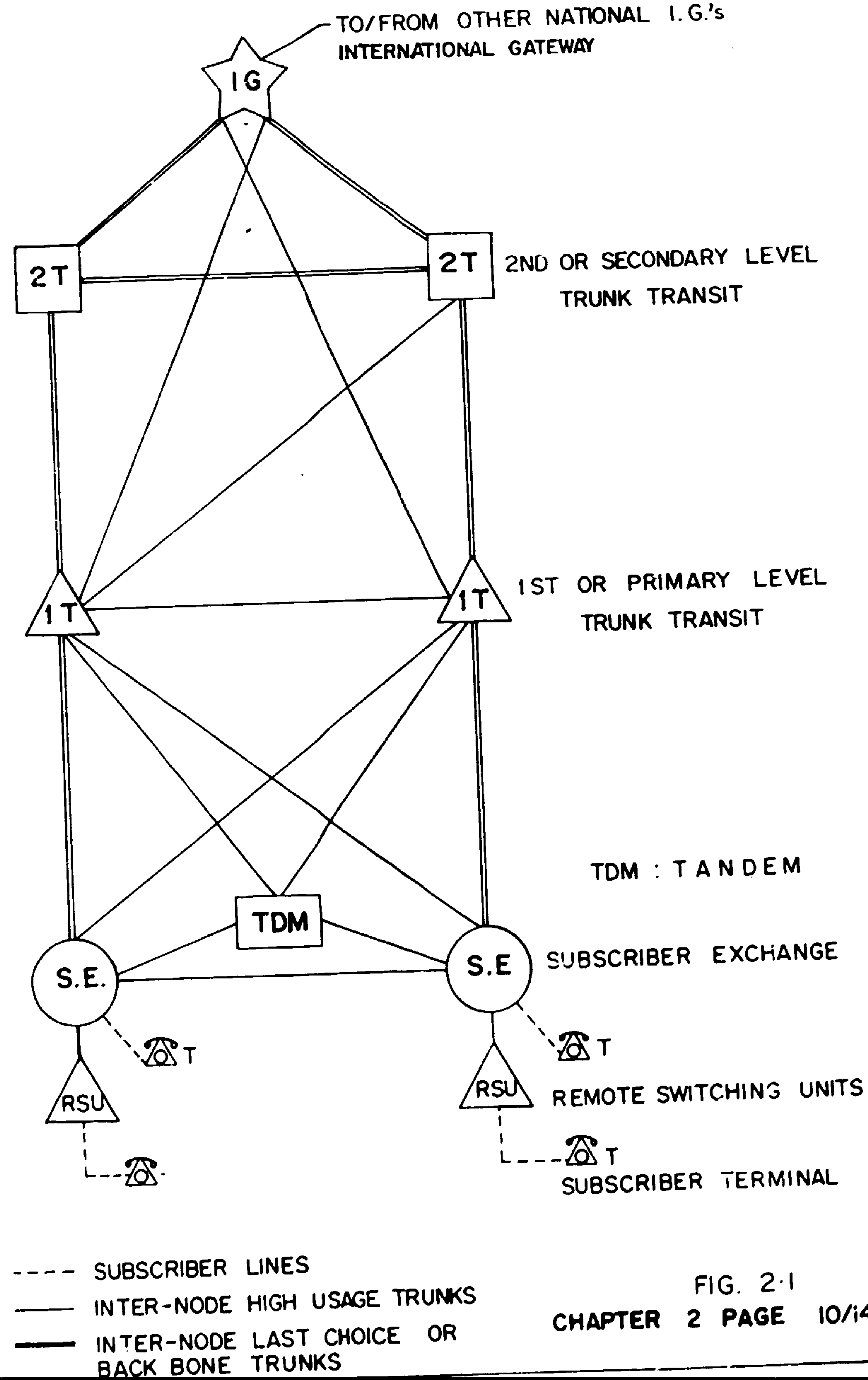
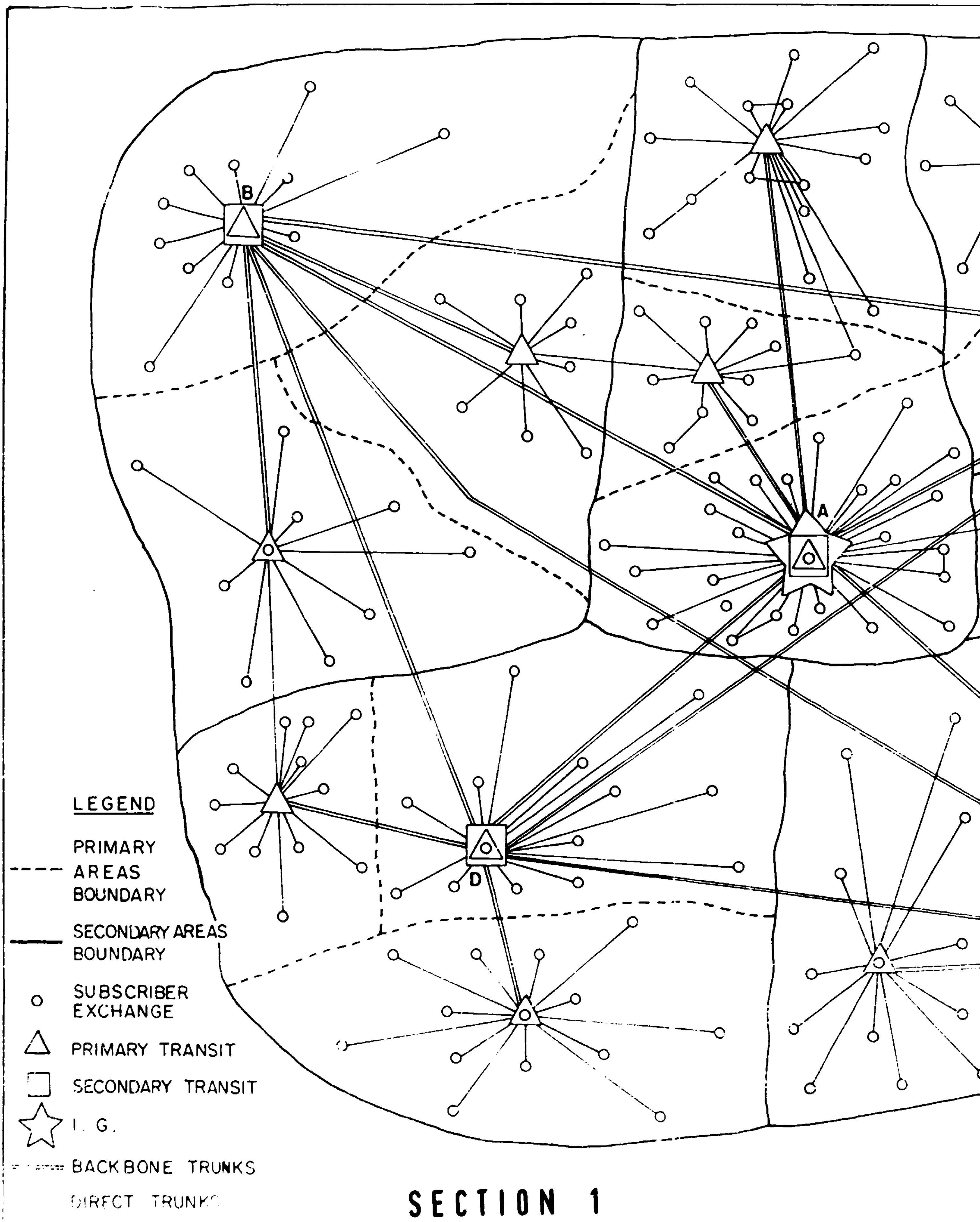


FIG. 2·1


B
A
D
LEGEND
PRIMARY AREAS BOUNDARY
SECONDARY AREAS BOUNDARY
SUBSCRIBER EXCHANGE
PRIMARY TRANSIT
SECONDARY TRANSIT
I. G.
BACKBONE TRUNKS
DIRECT TRUNKS

SECTION 1

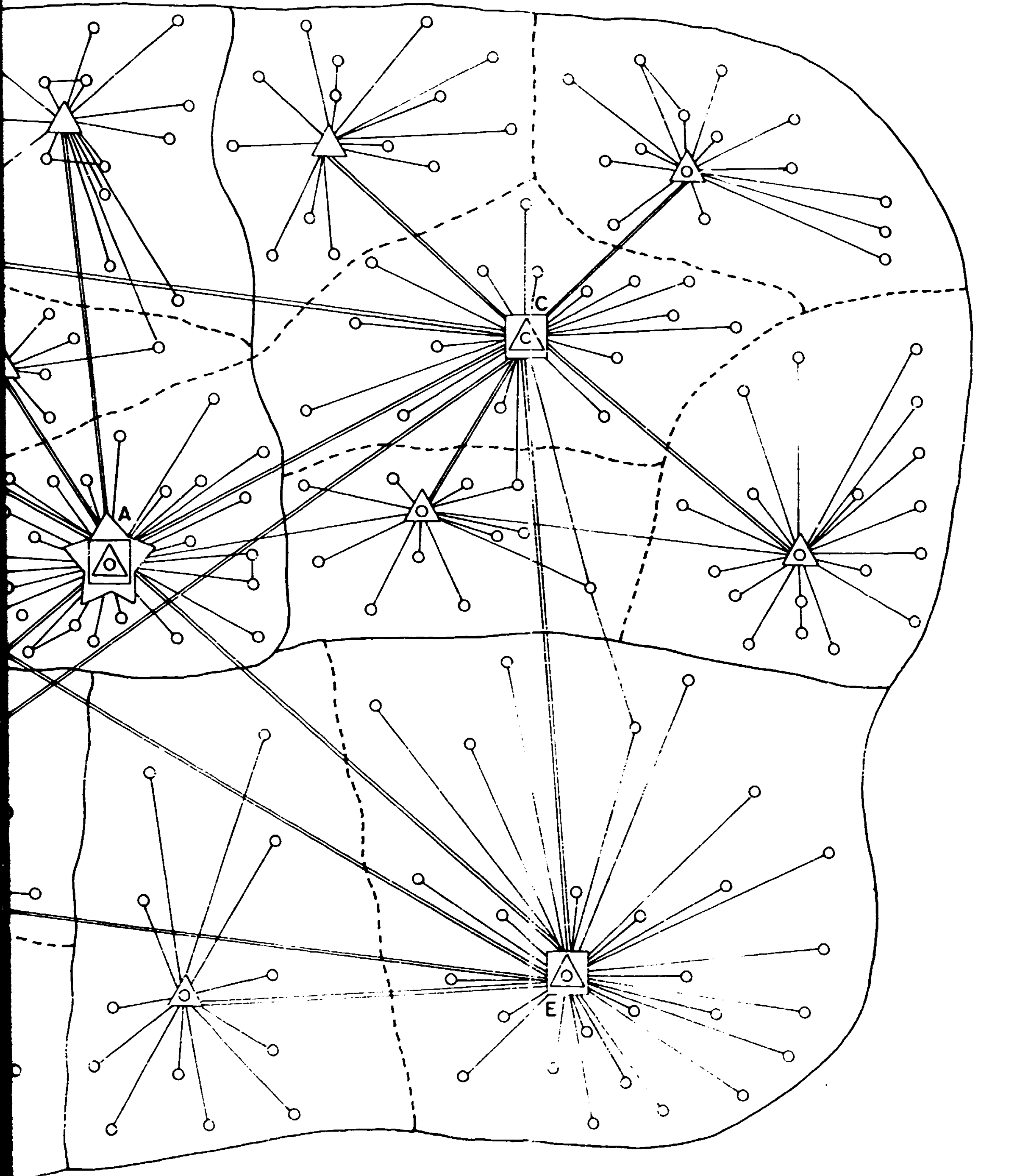


FIG. 2-2

A TYPICAL P S T N

Table 2.3

An indicative list of typical systems and products going into a National Public Switched Telephone Network

A. **Subscriber Instruments**

1. Telephone instruments
   - Standard single line
   - Extension plans
   - Multi-line & key systems
   - with cordless extensions
   - MARR & Cellular mobile

2. Telex instruments
   - Teleprinters
   - P.C.'s with telex cards

3. Modems for different data rates for use with data terminals

4. Facsimile terminals

5. Private Branch Exchanges

B. **Subscriber line components**

1. Multi- pair cables
   - For underground ducts, jelly filled polyethylene insulated unit twin polyethylene sheathed unarmoured.
   - For direct burial, as above but armoured with with galvanized steel tape.
   - For aerial suspension

2. Jointing materials
   - In line jointing modules
   - Jointing closures

3. Ducting
   - PVC, HDPE pipes & accessories
   - RCC materials

4. Main distribution frame for cable termination at exchange:
   - Iron work frame
   - Terminal strips for mounting gas discharge tubes and terminating cables and jumpers
   - Gas discharge tubes for lightning & power contact protection.
   - Jumper wire

Table 2.3 (continued)

B. Subscriber Line (continued)

5. Cabinet, pillars & D.P.'s (flexibility points)

- Steel or plastic housings
- Insulation displacement type terminal strips.

6. Line Jack Units for terminating lines at Subs premises

7. Single pair cable (Drop wire), for leading in subscriber line from a D.P. to the Line Jack Unit.

8. Subscriber line carrier systems

9. Subscriber line radio systems e.g. single channel VHF

10. Multi channel demand assignment radio systems e.g MARR and Cellular mobile.

C. **Switching nodes**

1. Subscriber Exchanges, various sizes

2. Remote Switching Units

3. Transit & Tandem Exchanges of various sizes

4. Integrated subscriber and transit exchanges

D. **Trunks & Junctions**

1. Optical fibre systems

- Optical fibre cables
- Digital multiplex systems &
- Optical line transmission systems of various capacities
    - 2 Mb/s, 30 channels
    - 8 Mb/s, 120 channels
    - 34 Mb/s, 480 channels
    - 140 Mb/s, 1920 channels
    - 565 Mb/s, 7680 channels
      and even higher order
- Various accessories

Table 2.3 (continued)

D. Trunks & Junctions (continued)

2. Terrestrial Digital radio relay systems, various frequency bands & capacities e.g.

- 4 & 6 Ghz 140 Mb/s 1920 channel.
- 11 & 13 GHz 34 Mb/s 480 channels.
- 2 GHz 8 Mb/s 120 channel.
- 400 & 600 Mhz 2Mb/s 30 channel and 10 channel systems.

3. Satellite based digital and analogue systems of various capacities in various frequency bands

- Large capacity multi channel systems
- Single channel per carrier systems
- Demand assignment systems. Analogue & TDMA

4. Accessories for radio relay systems,terrestrial & satellite based:

- Antennas of various types
- Wave guides, cables & feeders of various types
- Steel and other towers of various heights and load capacities

E. **Accessories & support equipment for all systems:**

1. Main Power plant for switching nodes and transmission stations :

- Float chargers from mains to 48 or 60 volts D.C. various capacities.

- Standby batteries: Lead acid various sizes

2. A whole range of Test Instruments, some of general application, others specialized for each type of equipment

3. Air conditioning plants of various sizes for exchanges & transmission stations

4. Fire detection and fire fighting equipment

5. A wide variety of equipment, transport, material handling, winches, and a wide range of tools for construction, installation and maintenance & operation

Chapter 3

Average cost per line, of national PST network & items and factors going into it

3.1 Essential Components of a PST Network

The main components of a national PSTN have been briefly discussed in chapter 2. The cost of each of these components spread over all the working subscribers' lines determines the average network cost per line. The network cost per line varies very widely from country to country and at different stages of development of the network in the same country. The actual cost of a specific line within the same network varies very widely from the average, depending upon the density of population and telephones, traffic, geographical topology and the location of the subscriber vis a vis existing network facilities.

3.2 Start up costs of a PST Network

3.2.1 The two essential requirements of an effective and efficient national PSTN are:

- Ability to provide access by way of a subscription service within a reasonable time after receipt of request for such service, to every citizen who wants such access and is willing to pay for it at reasonable tariffs, and

- prompt and effective establishment of a through channel for communication with any other subscriber anywhere in the world, at the will and command of the subscriber.

3.2.2 These requirements call for establishment of at least a skeleton hierarchy of switching nodes and an international gateway, with transmission trunks connecting them, again at least the basic backbone routes, very early in the development. In addition in urban areas it is neccessary to construct the underground cable ducts along at least the main thoroughfares with certain minimum subscriber cables to provide for connections anticipated within a reasonable period.

The start up costs of a network therefore tend to be high. This makes, the initial per line cost high, which, however comes down as the start up costs get distributed over more and more subscribers.

3.3 Factors affecting the cost per line in a mature PST Network with a large base of subscribers and a stable growth rate

3.3.1 In a mature network with a substantial base of subscribers and a fairly stable growth rate, the cost per line depends on the telephone density, size and topology of the country, and the calling habits of the users i.e. busy hour traffic in terms of simultaneous calls anticipated in different parts of the network which in turn depends on the busy hour calling rate and average duration of the calls. The network cost also depends on the target grade of service. All these are basic inputs for the engineeri g and configuration of the network. Good engineering and configuration, and proper selection of component systems can significantly reduce cost per line.

This brings out the importance of availabilty of well trained and competent network engineers, independent of the suppliers of equipment.

3.3.2 Apart from the above, the cost per line will naturally depend on the input costs per unit (by way of equipment and services) which the country can command. This in turn will depend on the extent of competition the country can secure in its purchases.

3.4 Typical per line costs in a typical PST Network at an intermediate level of maturity

3.4.1 Table 3.1 summarizes typical per line cost and its breakdown under major components, for a typical national PSTN at an intermediate level of development and maturity, with a base of between 500,000 to 1000,000 subscribers. The cost has been given for three types of areas in the network, high density, medium density and low density, the latter combined with difficult geographical topology such as hilly & mountaneous regions or a collection of low population density islands. The table gives per line cost for each component in US$ and as a percentage of total.

3.4.2 The cost have generally been based on the average international prices for equipment and supplies without any significant local government import duties or other taxes, prevailing during the period 1987-90. The networks have been assumed to have been engineered and constructed using digital switching and transmission.

The cost of infrastructure namely land and buildings, takes into account the relatively less expensive land and construction costs in developing countries.

In regard to construction and installation costs, while on one hand the significantly lower manpower costs prevailing in developing countries, have been taken into account, on the other, higher costs of engineering & supervision from suppliers, who in most cases, belong to the developed countries, and therefore rather costly, have also been kept in view.

3.4.3 The figures in table 3.1 indicate that the overall network costs will be of the order of 1000 US$ per line in high density areas, 1200 US$ in medium density areas and will be substantially higher of the order of US$ 2500 per line in very low density and geographically difficult areas.

3.5 Possibilities of reduction of network costs

3.5.1 The basic question before the proposed Bangalore meeting relates to the possibility of reducing the network investment costs in developing countries through:

- Joint action and cooperation among developing countries in procurement of telecommunication equipment

- Local or regional manufacture of equipment & components going into them

3.5.2 Before going into these aspects perhaps it will be appropriate to reiterate three points which have already emerged:

1) A good network engineering & configuration can significantly reduce the average network costs per line. For this, availability of competent network engineers independent of suppliers of equipment, is essential.

2) The unit manpower costs in developing countries are significantly lower than in developed countries. Availability of adequately trained and competent local manpower to undertake all the engineering, construction, installation, maintenance and operation will significantly reduce the average network cost.

3) Ability to secure adequate competition in purchase of equipment and services will help reduce the cost of essential inputs to the network.

3.5.3 Network segments requiring priority consideration:

While reduction in cost of every segment of the network will contribute to overall reduction of costs, it stands to reason that areas contributing the maximum to the average cost, need priority consideration. To help identify such priority areas, the per line network costs have been summarised in table 3.2 under six broad headings:

1) Subscriber instruments
2) Subscriber Lines
3) Switching systems
4) Transmission media
5) Operator services boards
6) Construction & installation

These costs have been further rearranged in tables 3.3, 3.4, & 3.5 in descending order seperately for high, medium and low density areas. The tables indicate that:

- In high density areas, switching system costs lead with a 38.8% share followed by subscriber lines with a 21.4% share.

- In medium density areas the switching system costs still lead though with a smaller share of 32.3%. The Subscriber line costs are still next but with a much larger share of 30.9%

- In very low density areas the transmission media costs overtake and become dominant with a share of about 60%.

The above analysis indicates the possibilities of somewhat different priorities among the developing countries according to their geographical topology and population distribution.

3.5.4 Local or regional manufacture of systems and components:

To help the Bangalore meeting to consider the possibilities of reduction of costs through local and regional manufacture of some of the equipment, a more detailed survey of important component systems and products going into the network has been undertaken in the following chapters. This includes a survey of the systems currently in use and being produced, their brief description, and an analysis of the essential inputs required for their production, by way of components and raw materials; machines, tools & testers; and manpower. Some idea of their international costs has also been given. In a seperate chapter, a similar analysis of inputs required for some of the more important components themselves has also been undertaken.

Annexed: Tables:

3.1 Per line component wise costs for a typical national PSTN.

3.2 Per line costs for a typical PSTN summarised under a few broad headings.

3.3 Per line costs for a typical PSTN, headings rearranged in descending order of costs in high density areas.

3.4 Per line costs for a typical PSTN, headings rearranged in descending order of costs for medium density areas.

3.5 Per line costs for a typical PSTN, headings rearranged in descending order of costs for low density areas.

Table 3.1

Per line component-wise investment costs for a typical national public switched telephone network (PSTN) to provide plain old telephone service (POTS) with capability to support low speed (upto 2400 bps) data transmission and facsimile (FAX) service

Areas of>>>	TYPICAL AVERAGE INVESTMENT COST PER LINE					
	High Density		Medium Density		Low Density	
Network component	US$	%	US$	%	US$	%
1. Electronic telephone with push button dialler, dial pulse/dtmf	25	2.4	25	2.1	25	1.0
2. Subscriber line on jelly filled copper conductor cables involving:						
a) Terminal jack at subs. premises	4	0.4	4	0.3	4	0.2
b) Drop Wire & fittings	15	1.4	20	1.7	25	1.0
c) Dist'n point	5	0.5	8	0.7	8	0.3
d) Cable duct PVC	50	4.8	80	6.6	0	0.0
e) Distribution cable *	80	7.7	150	12.4	150	6.0
f) Cable pillar	5	0.5	7	0.6	0	0.0
g) Primary cable	60	5.8	100	8.3	0	0.0
h) Main Dist'n Frame	4	0.4	4	0.3	4	0.2
Total subscriber line	223	21.4	373	30.9	191	7.6
3. Switching nodes						
a) Subscriber exchange	250	24.0	225	18.6	225	9.0
b) 1st transit exchnage	60	5.8	70	5.8	80	3.2
c) 2nd transit exchange	25	2.4	25	2.1	25	1.0
d) International Gateway	20	1.9	20	1.7	20	0.8
e) Infrastructure: buildings, air-conditioning, power plant etc	50	4.8	50	4.1	35	1.4
Total switching nodes	405	38.8	390	32.3	385	15.4
Total carried over to next page	653	62.6	788	65.2	601	24.0

Table 3.1 (continued)

Per line component-wise investment costs for a typical national public switched telephone network (PSTN) to provide plain old telephone service (POTS) with capability to support low speed (upto 2400 bps) data transmission and facsimile (FAX) service

Areas of>>> Network component	TYPICAL AVERAGE INVESTMENT COST PER LINE High Density US$	%	Medium Density US$	%	Low Density US$	%
Brought forward from previous page	653	62.6	788	65.2	601	24.0
4. Transmission media (equipment, cables, antenna, feeders etc)						
a) Trunks/junctions between Subs. Exchanges, and 1st. transit exchanges *	70	6.7	100	8.3	1,500	60.0
b) Trunks between 1st and second transit exchanges *	30	2.9	30	2.5	30	1.2
c) Trunks between 1st & 2nd transit and International gateway	30	2.9	30	2.5	30	1.2
d) International trunks	20	1.9	20	1.7	20	0.8
e) Infrastructure, ducts,buildings, air conditioning, antenna, power plant etc	20	1.9	20	1.7	20	0.8
Total transmission media	170	16.3	180	14.9	1,580	63.2
5. Operator services Boards etc	20	1.9	20	1.7	20	0.8
6. Construction & installation costs	200	19.2	220	18.2	300	12.0
Total investment per line	1,043	100.0	1,208	100.0	2,501	100.0
say	1,050		1,200		2,500	

Notes:

* Items 4(a) to (c) also include cost of direct trunks among the subscriber, 1st transit, and 2nd transit exchanges themselves.

* Some trade-off is possible between items 2(e) and 4(a) in case of low density areas. There is an alternative of providing service from a more centrally located exchange close to the parent primary transit node, using higher cost single channel VHF subscriber radio or multi-access radio relay systems for subscriber line in place of copper cables and thus reducing the cost of trunks to the 1st transit exchange. Such trade offs have to be considered to optimise the overall network costs in individual cases.

Table 3.2

SUMMARY OF
Per line investment costs for a typical national public switched telephone network (PSTN) to provide plain old telephone service (POTS) with capability to support low speed (upto 2400 bps) data transmission and facsimile (FAX) service

Areas of>>> Network component	TYPICAL AVERAGE INVESTMENT COST PER LINE High Density US$	%	Medium Density US$	%	Low Density US$	%
1 Electronic telephone	25	2.4	25	2.1	25	1.0
2 Subscriber line total	223	21.4	373	30.9	191	7.6
3 Switching nodes total	405	38.8	390	32.3	385	15.4
4 Transmission media total	170	16.3	180	14.9	1,580	63.2
5 operator services boards	20	1.9	20	1.7	20	0.8
6 Construct'n & installat'n	200	19.2	220	18.2	300	12.0
Total	1043	100.0	1208	100.0	2501	100.0

Table 3.3

Identification of the components contributing the maximum to per line investment costs for a typical national public switched telephone network (PSTN) to provide plain old telephone service (POTS) with capability to support low speed(upto 2400 bps) data transmission and facsimile (FAX) service

(high density areas)

Areas of>>>	TYPICAL AVERAGE INVESTMENT COST PER LINE High Density		Medium Density		Low Density	
3 Switching nodes total	405	38.8	390	32.3	385	15.4
2 Subscriber line total	223	21.4	373	30.9	191	7.6
6 Construct'n & installat'n	200	19.2	220	18.2	300	12.0
4 Transmission media total	170	16.3	180	14.9	1,580	63.2
1 Electronic telephone	25	2.4	25	2.1	25	1.0
5 operator services boards	20	1.9	20	1.7	20	0.8
Total	1043	100.0	1208	100.0	2501	100.0

Table 3.4

Identification of three components contributing the maximum to per line investment costs for a typical national public switched telephone network (PSTN) to provide plain old telephone service (POTS) with capability to support low speed (upto 2400 bps) data transmission and facsimile (FAX) service (Medium density areas)

Areas of>>> Network component	TYPICAL AVERAGE INVESTMENT COST PER LINE High Density US$	%	Medium Density US$	%	Low Density US$	%
3 Switching nodes total	405	38.8	390	32.3	385	15.4
2 Subscriber line total	223	21.4	373	30.9	191	7.6
6 Construct'n & installat'n	200	19.2	220	18.2	300	12.0
4 Transmission media total	170	16.3	180	14.9	1,580	63.2
1 Electronic telephone	25	2.4	25	2.1	25	1.0
5 operator services boards	20	1.9	20	1.7	20	0.8
Total	1043	100.0	1208	100.0	2501	100.0

Table 3.5

Identification of three components contributing the maximum to per line investment costs for a typical national public switched telephone network (PSTN) to provide plain old telephone service (POTS) with capability to support low speed (upto 2400 bps) data transmission and facsimile (FAX) service (low density areas)

Areas of>>> Network component	TYPICAL AVERAGE INVESTMENT COST PER LINE High Density US$	%	Medium Density US$	%	Low Density US$	%
4 Transmission media total	170	16.3	180	14.9	1,580	63.2
3 Switching nodes total	405	38.8	390	32.3	385	15.4
6 Construct'n & installat'n	200	19.2	220	18.2	300	12.0
2 Subscriber line total	223	21.4	373	30.9	191	7.6
1 Electronic telephone	25	2.4	25	2.1	25	1.0
5 operator services boards	20	1.9	20	1.7	20	0.8
Total	1043	100.0	1208	100.0	2501	100.0

CHAPTER 4

SWITCHING SYSTEMS

4.1 Introduction

The analysis in chapter 3 indicates that in a Public Switched Telephone Network (PSTN), the switching nodes contribute the maximum to the cost per line in both the high and medium density areas, and are a major cost component even in case of low density areas. In any consideration to reduce the network costs, switching systems naturally take priority. In this chapter a brief survey is undertaken of the switching systems now in use worldwide. This is followed by a brief generalised description of a typical system, and the major inputs required for an assebmbly plant for its manufacture viz. the major components that go into the production of a typical switching system, the machines, tools, testers and plant and the manpower required for such production. Rough estimates of costs are also indicated.

4.1 Switching systems in use worldwide

A wide variety of switching systems have been developed over the years and most are still in use, starting with manual switchboards, through elecromechanical step by step and common control systems, through SPC analogue systems to the fully digital systems.

4.1.1 Manual switching systems:

Ever since the invention of the Telephone by Alexander Graham Bell in 1876, there has been a continuous striving towards a cost effective network which will enable every person in the world eventually to have a telephone and converse on the same to anybody else anywhere. The service requires, besides the telephone instrument itself, a pair of conductors between the two parties for such conversation. It immediately became obvious that we could not run a pair of conductors from every telephone to every other, and some form of a switching network was inevitable. A beginning was made with the manual switching, in which subscriber lines were terminated on jacks suitably numbered with connections between desired lines established through patching cords by telephone operators. A hierarchy of switching nodes all manually operated, with appropriate signalling, routing and transmission plans soon developed and provided a fairly effective service in the beginning. However, apart from suffering from lack of secrecy, such manual systems became quite cumbersome as the number of users grew. Search for some means of automatic switching by various pioneers was on.

4.1.2 **Step by step electro-mechanical switching systems:**

Strowger switching system based on a two motion (vertical followed by rotary) switches was one of the earliest to be developed, in 1889, by Strowger, an undertaker, whose major motivation was diversion of his business through an operator, spouse of a competitor.The first practical exchange was installed in 1892. The system was perfected by various manufacturers and quite a few exchanges based on various versions of this technology are still in use, particularly in developing countries. In fact in India both manual switchboards and strowger step by step exchanges are still being produced and installed in small quantities because of their simplicity and low cost for quick provision of service in low density areas. However, they fall short of the requirements of modern networks by way of quality and reliability of service, and because of their lack of flexibility in numbering & routing add substantially to the overall network costs.

4.1.3 **Common control electromechanical systems:**

The need for some form of common control systems, which dislinked the numbering and routing of calls was felt very early. Efforts were made in this direction using the available eletromechanical switches. Notable examples are the the Director system developed by the British Post Office using the basic Strowger switches, the Panel system developed by AT&T in USA and the Motor Uniselector system of Siemens. Some of these were introduced as early as 1920's.

A real breakthrough in this direction became possible with the development of crossbar switches intially in USA and Sweden and later by others. The first crossbar exchanges under the name ' No. 1 Crossbar system' were installed by AT&T in USA in late 1930's. Using the crossbar switches higly effective, efficient and reliable common control networks with nation and world wide subscriber dialing were built up in 1950's and 1960's. Millions of lines of subscriber exchanges and hundreds of thousands of trunks of transit exchanges were installed in almost all the developed countries and some in developing countries.

4.1.4 **Stored Program Controlled switching systems**

Reliable, effective and efficient as the common control systems using crossbar switches were, they consumed very large quantities of precious materials and required considerable effort in installation, maintenance and administration of the network. The mechanical components were subject to considerable wear and tear. They also needed large amount of accomodation, particularly at a premium in large urban centres. On the other hand the newly emerging electronics and computer technologies promised newer switching systems with minimum of moving parts,and considerablly less effort in mainteance and administration with possibilities of a whole range of new facilities. Soon after the invention of the transistor, in 1950's, work started simultaneously, in many countries on what came to be known as stored program controlled (SPC) switching systems. For the switching network two alternatives were considered, one based on highly minitiaturized and hermitically sealed relay matrix and the other based on the newly emerging digital technology.

First trial installations started in USA in the beginning of 60's and the practicability of the idea was well established by mid 60's. By mid seventies a number of systems were being manufactured and installed by the leading Telecommunications manufacturers, most of them based on analogue switching matrix. A few million lines of these SPC Analog switches were installed in various parts of the world and are giving excellent service.

4.1.5 **Stored Program (SPC) Digital Switching**

4.1.5.1 While the SPC analogue systems using highly reliable relay matrices were being installed, work was concurrently going on for developing fully digital switches with the intention of elimininating all electro-mechanical moving parts and match with the highly successfull development of digital transmission systems. Millions of dollars were being invested in 1970's by all the leading telecommunication manufacturers to develop fully digital systems, and devices for them. The development of the integrated circuits gave a real filip to this development, and this development in turn gave a real filip to the development of eletronics.

4.1.5.2 By mid 70's France had made a real breakthrough with its digital switching systems being devloped by CIT Alcatel and Thomson CSF in close cooperation with French PTT. These switches laid the foundation for the remarkable transformation of the French network during late 70's and early 80's.

4.1.5.3 By early 80's most of the leading manufacturers had successfully completed and proved their digital switches. Since then each has won its own adherents based on various features including the cost and special efforts to woe particular markets. Each claims to have sold and installed millions of lines of local and thousands of trunks of transit exchanges. Most are manufacturing their switches to varying degrees in more than one country. Intense work is on to minitiaturise the devices, improve their reliability and build in new features. Everybody is working towards making his switch most modular and versatile for PSTN, for ISDN, for Cellular Mobile, and for what have come to be known as Intelligent networks, and make it cost effective for the entire range and size of applications.

4.1.6 **Current situation**

The current situation thus is that in different parts of the world a varying mix of earlier electro-mechanical systems, both step by step & common control, and SPC analogue switches are still working. The new installations are dominantly of the SPC digital type. Some of the administrations are even taking up programmes of replacing the existing older switches irrespective of whether they have completed their useful life.

As far as setting up of new production capacities is concerned it is today totally inconceivable to think of anything but the latest SPC digital switches. Accordingly in this report only these types of switching systems are being cosidered.

4.2 World's major SPC digital switches

4.2.1 Following are some of the major SPC digital switches (arranged in alphabetical order) and their original developers and manufacturers:

a)	AXE	Ericsson of Sweden
b)	DMS	Northern Telecoms of Canada
c)	E-10-B	Alcatel of France
d)	ESS 5	American Telephone Telegraph Corporation of USA
e)	EWSD	Siemens of Germany
f)	FETEX 150	Fujitsu of Japan
g)	NEAX 61	NEC of Japan
h)	System 12	Bell Telephone Manufacturing Co of Belgium
i)	System X	Plessey & GEC of UK

4.2.2 Besides tha above major systems, Italtel of Italy, Nokia of Finland, Oriental Telecom Co of Korea and ITI and C-DOT of India have also developed SPC Digital Switches, under the names Linea UT, DX 200, TDX, ILT and C-DOT RAX & MAX respectively. In most cases they are available for small and medium size exchange applications. Work is going on in some other countries also towards development of their own switching systems.

4.2.3 SPC Digital switches for PBX application

The above is by and large the current position in regard to switching systems for public networks. Many more systems have been developed and are being successfully produced and marketed by a large number of companies for the special application as Private Branch Exchanges. However, the Private Branch Exchanges have not been listed as a component under the PSTN in chapter 3, because in most countries there is a growing trend for the subscribers to directly buy these rather than lease them from the public service provider.

4.3 Brief Description of SPC digital switching systems

(This is necessarily a very elementary and general description meant as a brief Introduction for the non-technical readers).

4.3.1 High Level of commonality among various systems

Because of close international cooperation in the ITU and its CCITT towards standardization, and the nature of the digital and SPC technologies, there is a considerable conceptual commonality between different SPC digital switching systems. In most cases the hardware and construction practices have developed along parallel lines and many of the electronic devices used are similar if not the same.

4.3.1 Block Schematic

Fig 4.1 is a very generalised block schematic of a typical SPC digital exchange. All modern SPC digital systems are necessarily a highly sophisticated combination of hardware and software. However,in all systems, an attempt has been made to minimise complexity through adoption of functional modularity both in hardware and software. As figure 4.1 indicates at the overall level a digital exchange consists of three basic functional blocks.

- Subscriber Line and Trunk Block (SL&TB)
- A Digital Switching Network Block (DSNB)
- A Central or Coordinating Processor Block (CPB)

Each block in turn consists of a number of functional modules. For purposes of control each block and some of the modules have their own dedicated microprocessors thus ensuring a highly distributed control & effective modularity. The block & module level microprocessors, of course, continuously communicate with and are controlled by the central or coordinating processor.
The three blocks are interconnected by physical and logical links or highways.

4.3.2 Subscriber Line & Trunk Block (SL&TB)

The Subscriber Line and Trunk block consists of a number of Line & Trunk Groups of varying capacities in different systems. The Line and Trunk groups basically provide an interface between, on the one hand, subscriber lines and analogue and digital inter exchange (or node) trunks with different signalling systems, and on the other, a digital switching network. It scans the lines & trunks for on/off hook conditions, receives and transmits signals, and continuously monitors the correct functioning of its own modules.It also provides a point for concentrating (essentially low) traffic from the subscriber lines and when warranted from trunks.

Figure 4.2 gives a block diagram of a typical Subscriber line and Trunk block in a typical system. As can be seen it consists of:

- Subscriber Line Units (SLU),
- Analogue Trunk Line Units (TLU-A)
- Digital Trunk Line Units (TLU-B)
- Dual Tone Multi Frequency signalling, sending and receiving Unit (SU-DTMF).
- Tones/ Announcements / ringing current generating and sending Unit (SU-T&R)
- A Subscriber & Trunk line Group Switch (GS-SL&T)
- A Link Interface Unit(SL&T-LIU), and
- A Group Processor (SL&T-GPU)

4.3.2.1 A subscriber line unit (SLU) serves to connect upto 32 subscriber line interface circuits mounted on four modules or cards, serving 8 subscriber lines each. Each subscriber line interface circuit contains two miniature relays, a hybrid transformer and a codec per subscriber line. The circuit provides for line condition and off-on hook detection,ring feed, ring trip and analogue to digital and digital to analogue conversion for each subscriber line.

4.3.2.2 An analogue trunk line unit (TLU-A) serves upto 16 analogue trunks, mounted on four modules or cards. Each card mounts devices similar tc those for subscriber line card for signal detection, signal interface,2 wire/4 wire , and analogue to digital and digital to analogue conversion.

4.3.2.3 A digital trunk line unit (TLU-D) provides an interface between the exchange and 32 digital (A-law) trunks, giving a 2 Mb/s channel.

4.3.2.4 The two SU's or signalling units provide for signal generation and sending on to the Subscriber lines and trunks, one for DTMF signals and the other for ring current and other tones and announcements.

4.3.2.5 The subscriber and trunk line group switch (GS-SL&T) is a non-blocking one stage time switch designed to interconnect 512 channels. On one hand it connects the subscriber lines and trunks to the switching network for connection to subscribers and trunks served by other S&TL Blocks, on the other it interconnects the SU's to the Subscriber & Trunk line modules for transmission of necessary signals under control of central processor.

4.3.2.6 The subscriber and trunk line link unit (SL&T-LIU) provides the interface between the group switch (GS-SL&T) of the SL&T Block and the switching network block on a duplicated 8 Mb/s 128 channel PCM path.

4.3.2.7 The SL&T Group Processor, typically a processor with 64 Kbytes memory for data and program storage, adapts information arriving from the Subscriber lines and trunks to the internal standard interface of the exchange and controls the SL&T Group switch. It preprocesses some of the switching information e.g. the called subscriber number signals received from the calling subscriber and thus reduces the load on the central processor. Some of the more important functions performed by this processor are:

1) Scan the line for on hook/ off hook conditions
2) Control subscriber line & trunk circuits and group switch
3) Control signallig procedures
4) Perform timing operations e.g. for supervision & metering
5) Convert external line/trunk signals to internal standard messages for central processor & vice versa
6) Routine test line and trunk circuits, code generators, senders & receivers
7) Monitor switching network functions
8) Measure bit error rates
9) Scan alarm indications on PCM transmission systems

4.3.3 <u>Switching Netwok Block</u>

4.3.3.1 The switching network provides for digital interconnection between subscriber lines and trunks terminated on different Subscriber Line & Trunk blocks. Each such block is typically connected to the switching network through an 8 Mb/s path (128 channels of 64 Kilobits/s). For a voice path two such 64 Kb/s channels have to be through-connected from calling to called subscriber module, one each for each direction of transmission.

4.3.3.2 The switching network consists of a combination of two time and a space switch stage. and a network controller. The time switch stages serve to through connect the associated offering and serving channels by changing the time slots. The space switch stage on the other hand connects several time switches through space. It changes the position of the time division multiplex signals in space while keeping them in the same time slots.

4.3.3.3 The switching network consists of uniform time and space switch modules. whose number is decided by the size of the exchange and the traffic in erlangs. for example as shown in fig. 4.3. a switching network for interconnection of 8192 channels of 64 Kb/s will require two stages of 16 time switches each with a capacity to switch 4 channels of 8Mb/s and 4 space switches capable of switching 16 channels of 8 Mb/s.

4.3.3.4 The switching network controllers control the time and space switches to establish and release connections according to instructions from the central processor.

4.3.4 Central Processor

4.3.4.1 Functions

The central processor. sometimes also called coordination processor. performs three categories of functions:

a) Switching functions. e.g.:

- Number analysis for routing and zoning
- Path finding including alternative routing
- Evaluating and generating line/trunk messages

b) Exchange operation & maintenance including man-machine communications. e.g.:

- Installing & disconnecting subscriber lines
- Changing trunk group allocations
- Reading out call charge data
- Traffic measurements
- Testing. fault diagnosis

c) Safeguarding functions. e.g.:

- Locating & blocking faulty equipment
- Chageover
- Recovery. alarm and fault recording
- Selective or total automatic restart

4.3.4.2 **Component modules**

The Central processor consists of a number of modules. each duplicated for reliability. Typically there are the following modules:

- Memory Unit (MU)
- Processing Unit (PU)
- Input/output processor (IOP)

Also associated are:

- Message Buffer (MB)
- Back up memory(BM)
- Central Clock Generator (CCG)
- Operation & maintenace devices (OMD's)
- Modems for remote Operation & maintenace functions

4.3.4.3 **Information paths**

The central processor has duplicated digital data paths to the Subscriber line & trunk block processor. the switching controller in the switching network. and to time switches for exchange of data and instructions.

4.3.4.4 Various manufacturers have developed their own switching processors for use as central processors. Some have deleloped a range of such processors with different capacities in terms of maximum number of BHCA (Busy Hour Call Attempts) they can handle. for use as a duplicated pair in different sizes of exchanges. Others have adopted multiple processor configuration (n+1). with one single design of processor. to achieve the same result.

4.3.5 **Configuration of different sizes of exchanges and for different applications**

In the paragraphs 4.3.1 to 4.3.4 above a very brief survey has been undertaken of the hardware of a typical digital switching system. The systems consist of three distinct functional blocks and each block consists of a number of functional modules. These modules can be suitably put together to obtain exchanges for different applications and sizes.

4.3.5.1 Application-wise there can be three different classes of exchanges:

- Subscriber
- Transit
- Integrated subscriber cum transit.

The three versions can be achieved by suitably equipping the subscriber line and trunk blocks.

4.3.5.2 Capacity wise there are three parameters to consider

- The number of subscribers or trunks. which will determine the number of Subscriber line & trunk blocks and their modular content.

* The traffic in Erlangs, i.e. simultaneous number of calls during the busy hour, which will determine the number of time and space switch modules in the switching network block and the maximum number of lines or trunks that can be connected to a subscriber line and trunk block.

* The busy hour call attempts, which will determine the type of central processor in systems in which different duplicated processors have been developed for different capacities or number of central processors in systems in which n+1 configuration has been adopted.

4.3.5.3 It has been claimed for almost every switching system on the world market that it can be suitably configured to be cost effective for practically any size, as a subscriber exchange from less than 100 lines to 100,000 lines and as a transit exchange from a few trunks to as many as 60,000 with BHCA anything upto 600,000 to 800,000. Very high reliability has also been claimed for the system as a whole and for individual modules,through choice of components and duplication of all critical functional modules.

4.3.6 Software

Paragraphs 4.3.1 to 4.3.2 have briefly covered the hardware of a typical digital switching system. In parallel and integral to the functioning of the system is the software, a sort of decision matrix and instruction set.

4.3.6.1 Software modules

As in the case of hardware, the software in modern digital switchnig systems has been developed in functional modules. The software can be broadly divided into two classes:

* The executive programs
* Data

4.3.6.2 The executive programs can be divided into three functional categories :

* Switcning programs
* Operating programs
* Safeguarding programs

Under each of these heads will be tasks similar to those described under para 4.3.4.1 for the central processor. There are separate program modules for processors in each functional block to cover each of these categories of functions.

4.3.6.3 Exchange data can be divided into equipment and function related, as also permanent, semi-permanent and variable.

Some idea about the extent of software, program & data can be guaged from the fact that a typical 20,000 line subscriber exchange with a BHCA of about 240,000 calls for a central processor memory of about 8 Mbytes, equal to about 40,000 pages of A-4 size typed matter in single space.

4.4 Prevailing prices for switching systems

4.4.1 As mentioned in paragraph 4.3.5 switching nodes are built up by putting together a large number of functional modules along with the necessary software. The traffic capacity in erlangs and BHCA and the network configuration vary very widely. It is therefore not possible to indicate a very precise per line cost for switching systems. Further the quotations given by different suppliers in the same tender tend to vary widely, as also quotations of the same supplier in different tenders. Thus in International competitive bids, on an overall basis, quotations have differed from about 150 US$ per line to 450 US$ per line. However in general the actual orders placed in different countries seem to lie in the range of 180 to 250 US $ per line FOB country of origin.

4.5 Manufacture of a typical digital switching system

4.5.1 As indicated in paragraph 4.3 above the basic hardware unit of a digital switching system is a module or printed card with a number of electronic components,active and passive mounted on it and interconnected to each other through conducting metal lines printed on the board. to perform a specific function in the system.

A number of these cards can be mounted in a frame. The connections between different cards are made through male/female connectors through a mother board or back plane, which is another printed circuit board, with suitable connectors mounted and interconnected.

A number of these frames are mounted on a rack. The connections between frames on the same rack and on other racks are made by means of connectorised cables. Each rack has its own power 48 or 60 volts D C supply distribution for the various frames and cards.

The manufacture of the switching system hardware can thus be considered in two parts.

- Procurement of various components and their assembly on cards, frames and racks and their testing.
- Manufacture of components.

4.5.2 In general, the assembly line production of different types of electronic systems has become a fairly standard process with standard manual, semi-automatic and automatic machines for card assembly, and wave soldering and semi-automatic and automatic test set ups. On the other hand the manufacture of components involves a very wide variety of processes, some of them highly complex and critical. The high reliability and performance repeatability requirements of components require a very high degree of automation and control.

In the remaining paragraphs of this chapter production process and inputs required for assembly production of a typical digital switching system are cosidered. Production of some typical components is considered in another chapter.

4.5.3 **Production process**

Chart 4.4 gives a typical assembly production process chart for a typical digital switching system

4.5.4 **The essential inputs for the assembly line manufacture of a digital switching system :**

These can be considered under three categories as follows:

- A very wide variety and types of electronic components.
- A fairly well standardized range of testing and assembly equipment and the necessary infrastructure.
- A set of well trained and competent operators, testers, software and hardware engineers and managers etc.

4.5.4.1 **Components and their cost**

Table 4.5 lists the different categories of components, the number of types, and the quantity of each category of components used in a typical switching system for an annual production of about 200,000 lines of a mix of small, medium, and large sized subscriber exchanges. Also included is an indicative international unit price for each component and an estimate of total cost of components per line. In view of the importance, and wide variations in prices of one category of components viz. I.C.'s table 4.6 undertakes a more detailed analysis of the types & their prices and arrives at an average price adopted in table 4.5.

The prices are based on certain budgetary quotations for component kits for a particular type of switching equipment during 1990. Significant discounts upto 10 to 15% may be feasible when purchased in bulk on regular basis. In respect of certain items particularly the IC's, prices tend to be high initially when a new device is introduced, but drop quickly with increase in sales volume.

4.5.4.2 **Production machines, tools and testers**

Table 4.7 gives a typical list of the testing and assembly equipment for two sets of assembly plants to produce 200,000 and 500,000 lines of a similar mix of small, medium and large subscriber exchanges per annum. A rough estimate of average international prices for such equipment has also been indicated. Table 4.8 summarises the cost of different classes of testing and assembly equipment and the infrastructure in a developing country.

4.5.4.3 **Manpower:**

A switching system assembly plant requires the services of operatives for the assembly work, testers and supervisors for detailed testing of modules in production and for system integration as a working exchange before shipment, technical staff for maintenance of machines tools & testers and engineers for both the hardware and software. In addition as in any other plant, it will require managers, accountants, sales force and buyers.

Table 4.9 gives an estimate of the manpower requirements and annual costs involved for the 200,000 and 500,000 lines p.a. plants in typical developed and developing countries.

4.5.5 Summary of Input requirements

4.5.5.1 Components

- Table 4.5 shows that the component requirements for assembly line production of 200.000 lines per annum of a mix of subscriber line exchanges will cost about US $ 13.8 million or about US $ 69 per line. This is a very rough estimate on the basis of prevailing international prices, FOB country of origin in small lots. Some discounts might be possible for large lots. Some additional expense will have to be incurred on freight and insurance. The two may balance out.

- The table covers basically the main exchange equipment only. It does not cover the main distribution frame which has been included under subscriber line in table 3.1, as also the standby batteries and float and charge rectifiers for the main 48 or 60 volts DC supplies, which have been included in the exchange costs.

  - A further analysis of component costs will indicate that the following items contribute the maximum to the component costs:
  - Integrated Circuits roughly contribute about 28 to 30% of the total component costs
  - Connectors of various types roughly contribute about 20 to 23% of the total component costs
  - Transistors of various types contribute roughly 12 to 13% of the total component costs
  - Printed circuit boards, hybrid micro circuits and cables are other large cost items each accounting for between 5 to 8% of the total component costs.

This analysis indicates need for priority attention to these items in any scheme of regional cooperation for production of components.

4.5.5.2 Plant, machinery & Testers

Table 4.7 indicates that:

- the investment required for setting up plants with 200.000 and 500.000 lines per annum assembly level production on plant, machinery and tools and testers will work out to about 7 and 11 million US$ respectively i.e. about 35 and 22 US$ of per line production per annum of this:

  - the investment on basic infrastructure, land, buildings, environmental control,water & power works out roughly at 2.5 and 3.8 million US$ respectively.
  - the investment on procurement of machinery,tools & testers works out at about 3.6 and 5.9 million US$ respectively, FOB country of origin. The freight, insurance etc may work out at 20% and erection, installation and test runs may involve another 20% of the procurement costs.

- Bulk of the costs are in testing and software generation equipment rather than in assembly and production machines. In general,to take advantage of inexpensive manpower costs in developing countries. simple machines. semi-automatic & manual have been indicated, except where automation is essential to ensure quality and reliability.

- The capital recovery requirements @ 33% per annum (assuming a life of 4 years and a compound interest of 12%)work out to roughly 2.3 and 3.6 million US$ respectively for the 200,000 and the 500,000 lines p.a. plants i.e. about 11.5 and 7.2 US$ per line.

4.5.4.3 Manpower costs

Table 4.9 indicates the manpower requirements and their annual cost, in a developed and a developing country respectively. It has been assumed that number and level of personnel required will be same but the Unit manpower costs will vary very significantly between the developed and developing countries. The table estimates the figures at US$ 42 and 3.6 for production of 200,000 lines a year and US$ 30 and 2.5 for production of 500,000 lines a year,in a developed and a devloping country.

This points to a significant potential for cost reduction by setting up plants in developing countries. At 200,000 lines per annum plant capacity the potential for saving works out to about 38 US$ per line and at 500,000 lines per annum at 27 US$ per line, which could be almost 30% and 22% respectively of the total production costs, in a developing country.

In practice, margin gets significantly reduced by resort to greater automation and increase in the size of production facilities in developed countries.

- The advantage has also tended to be lost in many developing countries due to fairly heavy local tax imposts on imported inputs by way of capital equipment as well as components.

- Another important element of cost is the amount charged by the original developing company by way of knowhow and royalty to reimburse it towards the cost of development.

Annexed:

Figures:

4.1: Basic functional blocks of a typical SPC digital switching system

4.2: Block schematic of a typical subscriber line and trunk block.

4.3: Typical duplicated TST switching network

Chart:

4.4: Typical process flow chart for assembly level production of a typical digital switching system

Tables:

4.5: Typical component requirements for production of 200.000 lines of a typical digital switching system

4.6: Typical distribution of various types of Integrated circuits (IC's) for production of 200.000 lines of a typical digital switching system.

4.7: Typical plant (machines, tools and testers) required for 200,000 and 500,000 lines a year of a typical digital switching system.

4.8: An indicative estimate of total investment required in a plant for assembly level production of a typical digital switching system

4.9: An indicative estimate of manpower required for assembly level production of 200.000 and 500,000 lines per annum of a typical digital switching system and an estimate of manpower costs per line in a developed and a developing country.

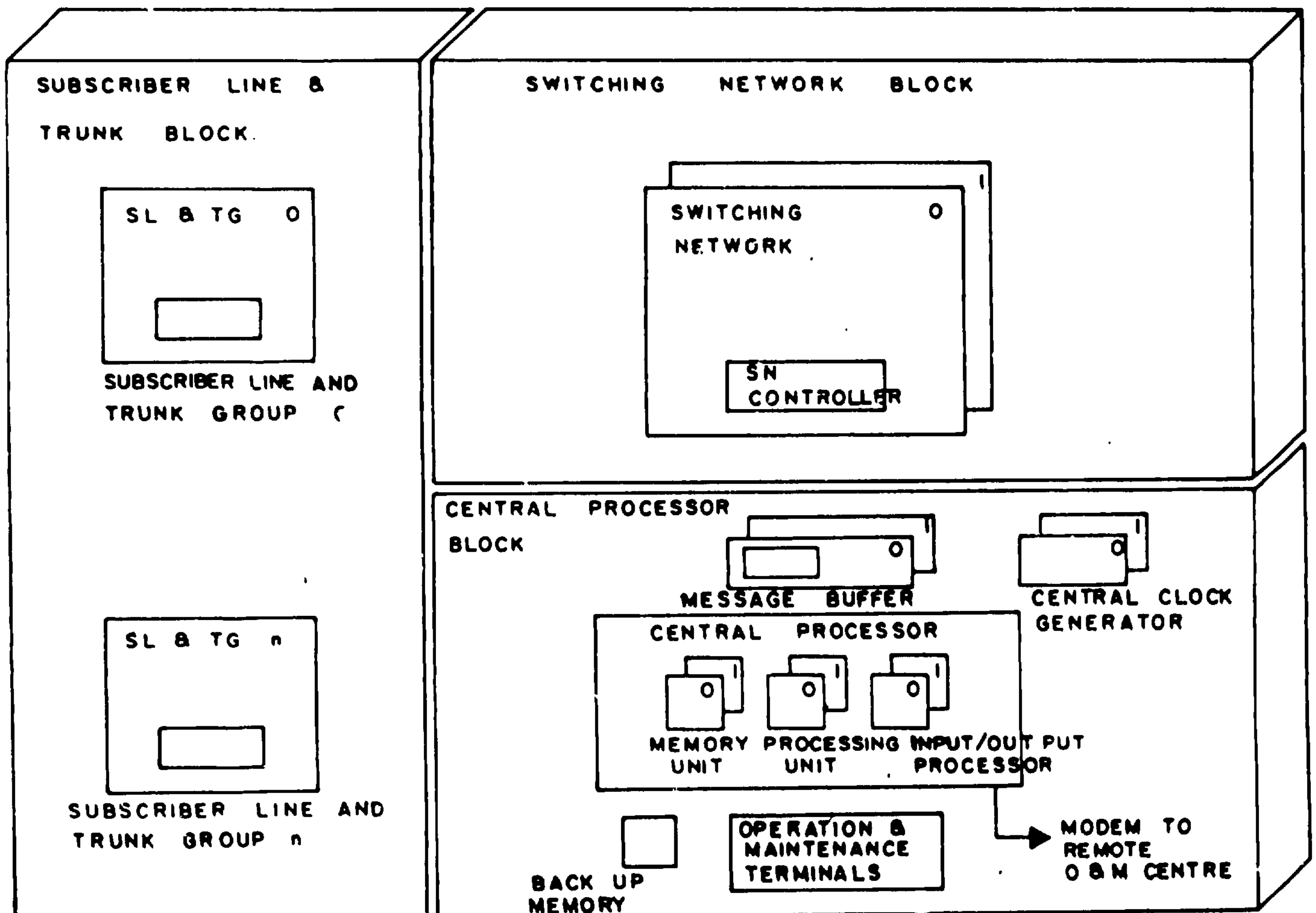


FIG 4.1 BASIC FUNCTIONAL BLOCKS OF A TYPICAL SPC DIGITAL SWITCHING SYSTEM

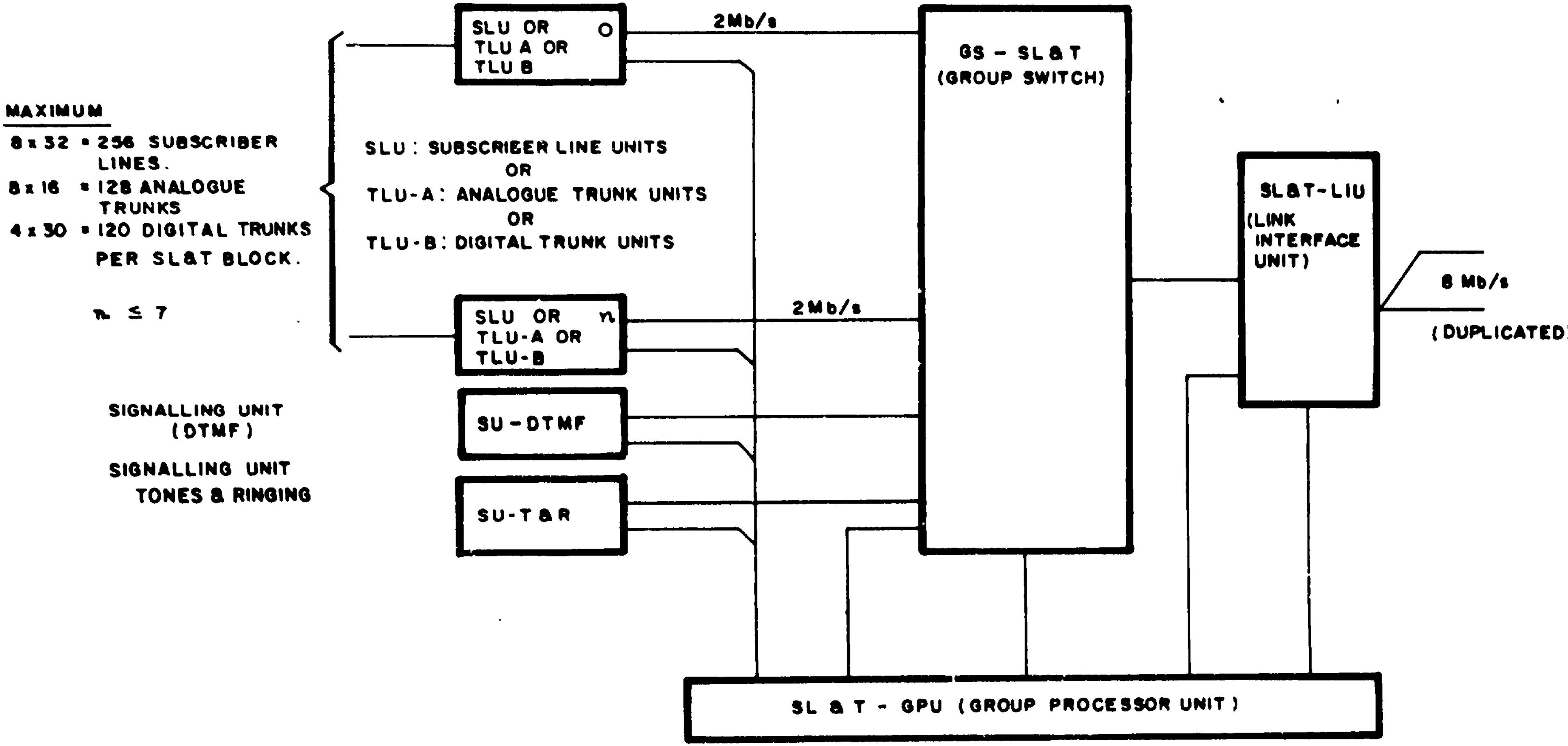


FIG 4·2 BLOCK SCEMATIC OF A TYPICAL SUBSCRIBER LINE & TRUNK GROUP IN THE SUBSCRIBER & TRUNK LINE BLOCK

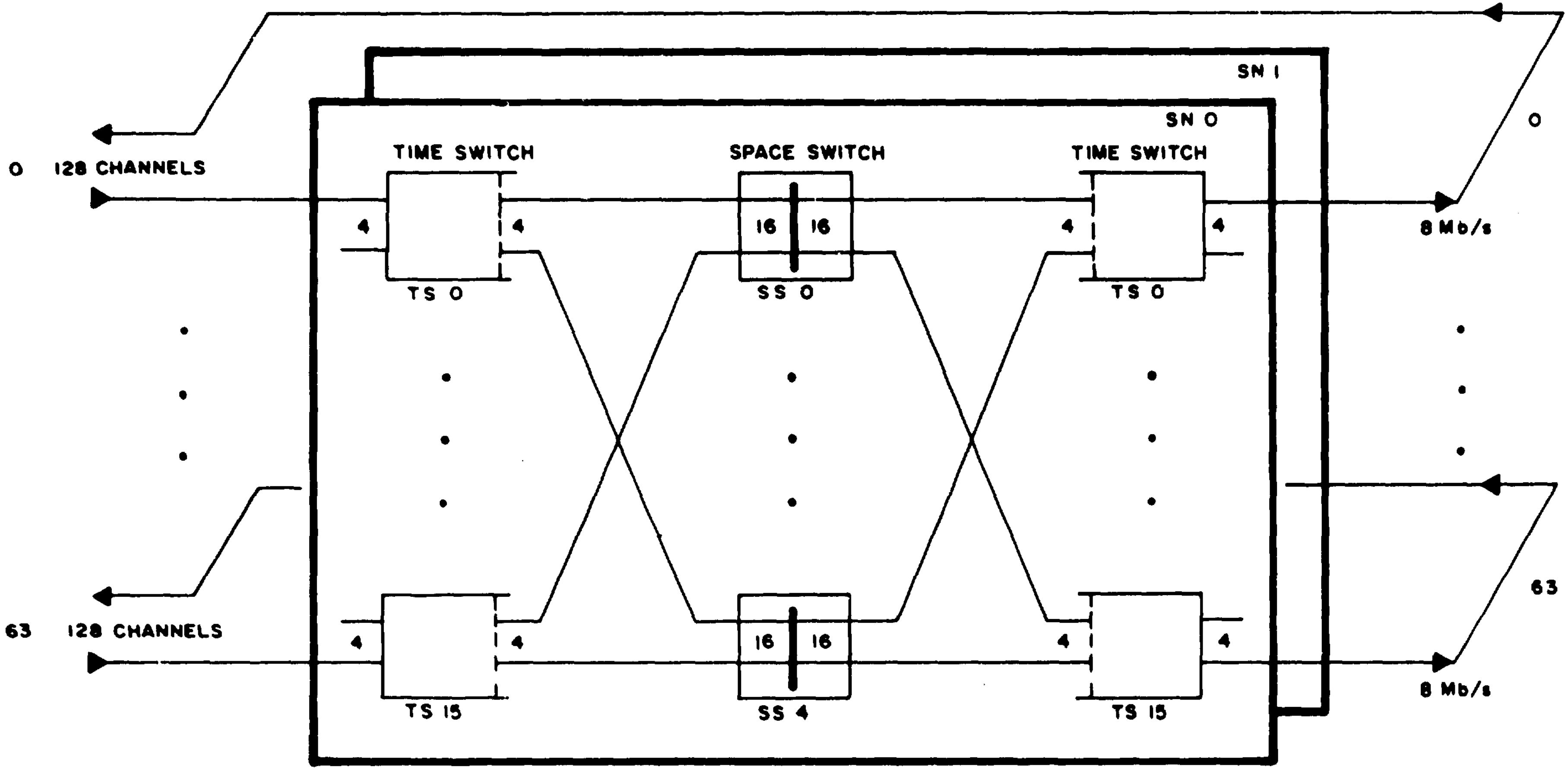
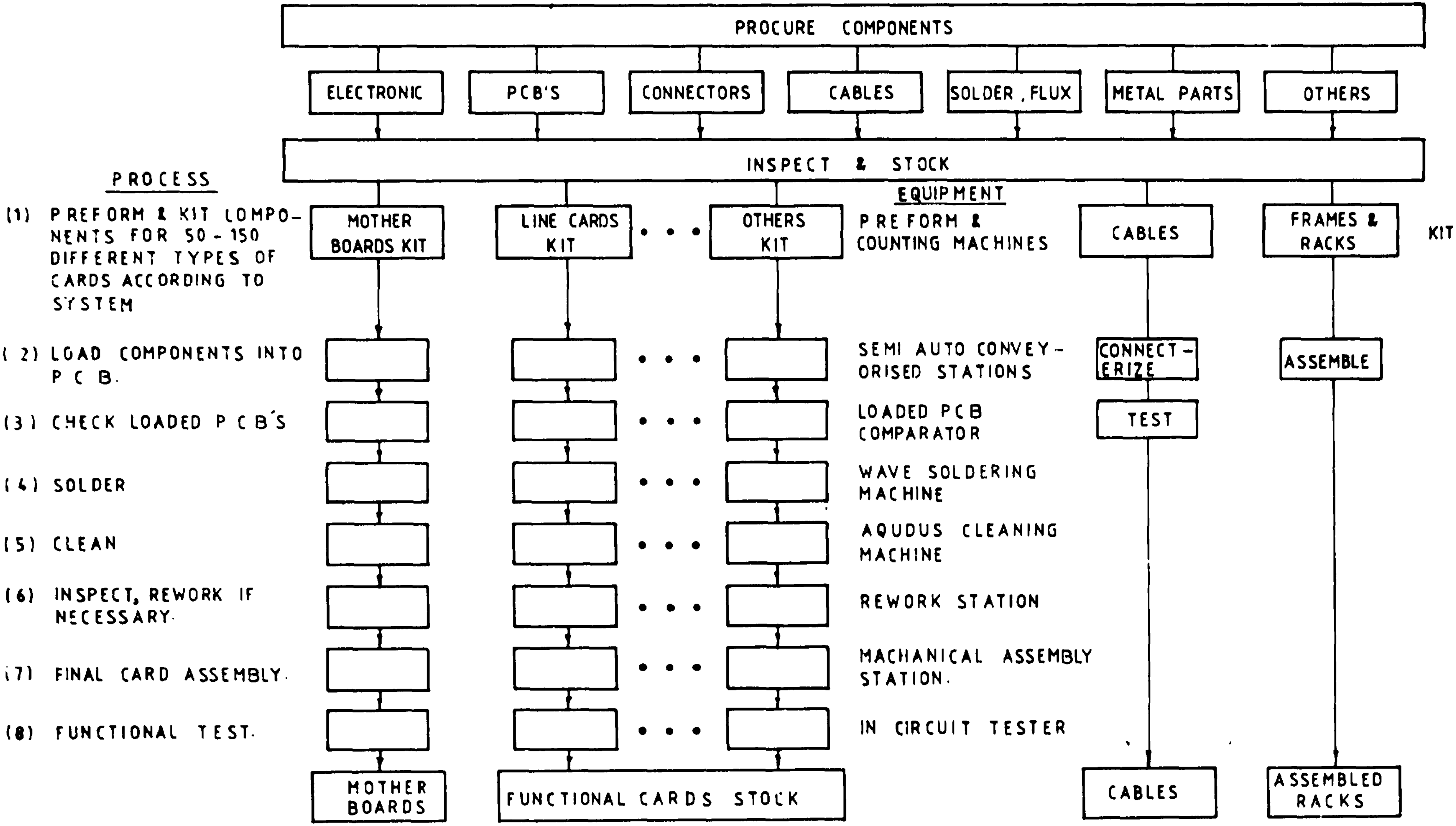


FIG 4·3 TYPICAL DUPLICATED T.S.T. SWITCHING NETWORK FOR INTER CONNECTING 8192 CHANNELS OF 64 kb/s

CHART 4.4

TYPICAL PROCESS FLOW CHART FOR PRODUCTION OF A TYPICAL SPC DIGITAL SWITCHING SYSTEMS
(BASED ON ASSEMBLY FROM ENTIRELY BOUGHT OUT COMPONENTS)



(CONTINUED)

CHART 4·4 (CONTINUED)

SYSTEM INTEGRATION

(1) FIT MOTHER BOARDS ON RACKS

(2) INTERCONNECT FRAMS ON SAME RACKS

(3) JACK IN FUNCTIONAL CARDS

(4) INTERCONNECT RACKS

(5) CONNECT POWER & LOAD SOFTWARE

(6) FUNCTIONAL, TRAFFIC LOAD TEST & HEAT RUN

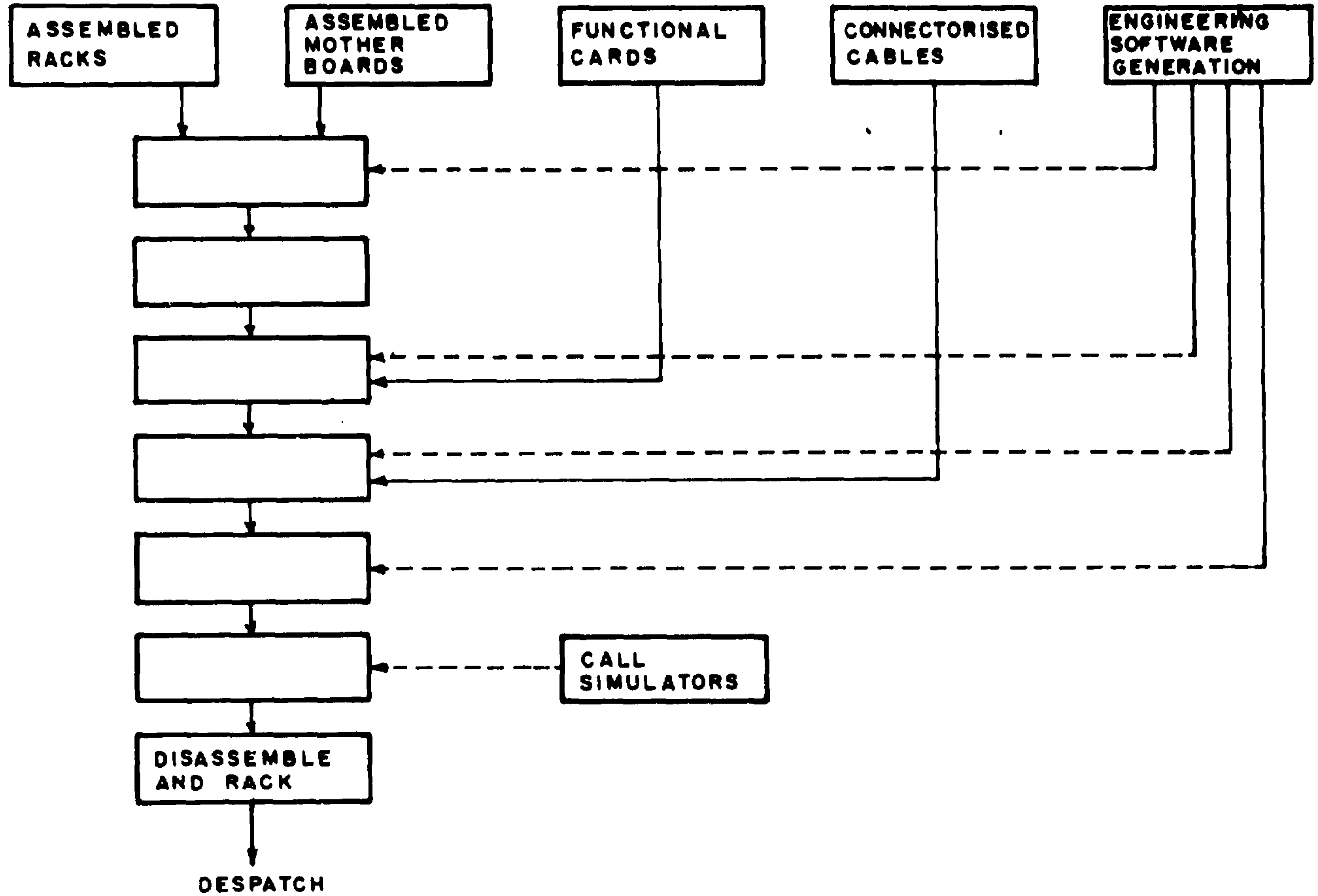


Table 4.5

TYPICAL COMPONENT REQUIREMENTS PER 200,000 LINES OF A TYPICAL DIGITAL TELEPHONE SWITCHING SYSTEM (FOR A MIX OF SMALL MEDIUM & LARGE EXCHANGES)

COMPONENT	Types Used no.	Qty. Used (00000)	------ Average Price US$ per	Total US$	----- $
1. Capacitors					
Ceramic	15	20.8	30 /000	62,400	0.5
Cermet Trim Pot	2	1	35 /000	3,500	0.0
Electrolytic	23	2	60 /000	12,000	0.1
Metalised Polyester	2	2.4	60 /000	14,400	0.1
Polystyrene	3	0.19	75 /000	1,425	0.0
Tantalum	5	0.79	150 /000	11,850	0.1
2. Coils & Transformers					
Chokes	7	0.2	250 /00	50,000	0.4
Line Transformers	1	2	250 /00	500,000	3.6
Power Transformers	9	0.37	250 /00	92,500	0.7
3. Connectors					
Backplane (set of)	8	0.024	1000 /set	2,400,000	17.40
IC Sockets	6	0.89	100 /000	8,900	0.06
Reverse Euro 64 pin	1	0.84	500 /00	420,000	3.05
Reverse Euro 96 pin	1	0.16	600 /00	96,000	0.70
Single row strip	1	1.14	760 /000	86,640	0.63
4. Crystals					
Oscillators	4	0.15	500 /00	75,000	0.54
5. Diodes					
Fast recovery	9	1.6	40 /000	6,400	0.05
General purpose	4	8.4	20 /000	16,800	0.12
Zener	8	10	50 /000	50,000	0.36
6. Ferrites					
Pot Cores	8	0.51	100 /00	51,000	0.37
Rods	1	0.04	100 /000	400	0.00
Torroidal Cores	1	0.04	200 /000	800	0.01
7. Hybrid Micro circuits					
HMC's	1	2	400 /00	800,000	5.80
Resistor Networks	7	0.69	300 /000	20,700	0.15
8. IC's					
SSI,MSI & LSI's	207	44	884 /000	3,889,600	28.20
* (Illustrative range indicated in table 4.6)					
9. LED's & LCD's	8	1.2	80 /000	9,600	0.07
10. Mechanical Hardware					
Racks/Cabinets	1	0.003	100 /pc	30,000	0.22
Frames	1	0.016	50 /pc	80,000	0.58
Total carried over to next page				8,789,915	63.73

TABLE 4.5 (Continued)

TYPICAL COMPONENT REQUIREMENTS PER 200,000 LINES
OF A TYPICAL DIGITAL TELEPHONE SWITCHING SYSTEM
(FOR A MIX OF SMALL MEDIUM & LARGE EXCHANGES)

COMPONENT	Types Used no.	Qty. Used (00000)	Average Price US$ per	Total US$	$
Total brought forward from previous page				8,789,915	63.73
11. PCB's					
Double Layer (VARIOUS)	V	0.61	15 /pc	915,000	6.63
Four Layer	1	0.1	35 /pc	350,000	2.54
Mother Board	1	0.024	50 /pc	120,000	0.87
12. Relays Miniature					
2-changeover contact	1	2	800 /000	160,000	1.16
4-changeover Contact	1	2	180 /00	360,000	2.61
13. Resistors Metal film	75	48	15 /000	72,000	0.52
Wire wound	7	0.32	25 /000	800	0.01
14. Transistors pcs	10	8.8	200 /00	1,760,000	12.76
15. Drives Winchester	1	600	200 /pc	120,000	0.87
Cartridge	1	600	100 /pc	60,000	0.44
Omti Controller	1	600	80 /pc	48,000	0.35
Monitors	1	600	60 /pc	36,000	0.26
16. Miscellaneous					
cables, cable connectors, fuses, screws, washers etc	lot		5 /line	1,000,000	7.25
Total cost of components for 200,000 lines				13,791,715	100.00
Cost of Components per line			US$		69

Notes:

1. The above analysis of components etc required for 200,000 lines is based on the following product mix:

Nominal capacity of Exchange, in lines	No of Units	Total Capacity
10000	6	60,000
5000	12	60,000
2000	25	50,000
500	40	20,000
100	100	10,000
Total	183	200,000

Table 4.5(continued)

Notes Continued:

2. The types and quantities of components etc indicated above are essentially only typical and illustrative. The details of actual components used and quantities are a fairly closely guarded confidential information, and is available only through formal commercial/technical collaboration agreements.

3. The prices of components in this and in next table are based on certain budgetary quotations for component kits for production of a particular switching system during 1990. Significant discount upto 10 to 15% may be feasible for purchase in bulk on a regular basis.

4. In case of certain components, particularly IC's, prices of new devices tend to be high initially but drop rapidly with increase in sales volume.

Table 4.6

Typical Distribution of various types of IC's used IN A TYPICAL DIGITAL TELEPHONE SWITCHING SYSTEM

(approximate quantities for 200,000 lines production)

Category of Integrated Circuits		QTY. used (no.'s)	Unit price US$	Total cost US$
A. TTL FAST				
Type	1	10,068	0.125	1,259
	2	6,712	0.125	839
	3	16,780	0.125	2,098
	4	25,170	0.125	3,146
	5	6,712	0.125	839
	6	3,356	0.125	420
	7	10,068	0.220	2,215
	8	28,526	0.138	3,937
	9	52,018	0.170	8,843
	10	16,780	0.200	3,356
	11	6,712	0.300	2,014
	12	6,712	0.285	1,913
	13	1,007	0.240	242
	14	12,585	0.510	6,418
	15	2,517	0.500	1,259
	16	10,068	0.350	3,524
	17	10,068	0.350	3,524
	18	3,356	0.380	1,275
	19	25,170	0.380	9,565
	20	67,120	0.380	25,506
	21	13,424	0.380	5,101
	22	3,356	0.490	1,644
	23	35,238	0.380	13,390
	24	839	4.800	4,027
	25	26,848	0.450	12,082
	26	8,390	0.350	2,937
Total TTL FASt		409,600	0.296	121,370

Table 4.6(continued)

Typical Distribution of various types of IC's used IN A TYPICAL DIGITAL TELEPHONE SWITCHING SYSTEM
(approximate quantities for 2000,000 lines production)

Category of Integrated Circuits		QTY. used (no.'s)	Unit price US$	Total cost US$
B:	TTL -High Speed			
Type	1	33,560	0.120	4,027
	2	12,585	0.120	1,510
	3	5,034	0.120	604
	4	58,730	0.120	7,048
	5	125,850	0.120	15,102
	6	8,390	0.120	1,007
	7	79,705	0.120	9,565
	8	92,290	0.180	16,612
	9	1,678	0.124	208
	10	8,390	0.124	1,040
	11	1,678	0.124	208
	12	58,730	0.124	7,283
	13	151,020	0.124	18,726
	14	218,140	0.155	33,812
	15	16,780	0.220	3,692
	16	8,390	0.180	1,510
	17	8,390	0.210	1,762
	18	117,460	0.200	23,492
	19	12,585	0.210	2,643
	20	8,390	0.250	2,098
	21	159,410	0.210	33,476
	22	1,678	0.270	453
	23	8,390	0.600	5,034
	24	285,260	0.228	65,039
	25	58,730	0.270	15,857
	26	12,585	0.245	3,083
	27	8,390	0.320	2,685
	28	12,585	0.240	3,020
	29	20,136	[illegible]	4,833
	30	20,975	[illegible]	8,600
	31	1,678	[illegible]	755
	32	37,755	[illegible]	11,327
	33	58,730	[illegible]	19,381
	34	4,195	[illegible]	1,384
	35	1,678	[illegible]	503
	36	1,678	[illegible]	755
	37	1,678	[illegible]	755
	38	226,530	[illegible]	63,428
	39	50,340	[illegible]	20,136
	40	2,517	[illegible]	856
Total CF		2,002,693		413,309

Table 4.6(continued)

Typical Distribution of various types of IC's used
IN A TYPICAL DIGITAL TELEPHONE SWITCHING SYSTEM
(approximate quantities for 2000,000 lines production)

Category of Integrated Circuits	QTY. used (no.'s)	Unit price US$	Total cost US$
B. TTL -High Speed (continued)			
B.F.	2,002,693		413,309
Type 41	4,195	0.240	1,007
42	4,195	0.285	1,196
43	1,678	0.400	671
44	12,585	0.320	4,027
45	20,975	0.280	5,873
46	4,195	0.320	1,342
47	3,356	0.550	1,846
48	4,195	0.550	2,307
49	12,585	0.700	8,810
50	1,678	0.700	1,175
51	16,780	0.125	2,098
52	1,678	0.380	638
53	8,390	0.240	2,014
54	3,356	0.200	671
55	6,712	0.950	6,376
total TTL HS HC series	2,109,246	0.215	453,359

Table 4.6 (continued)

Typical Distribution of various types of IC's used
IN A TYPICAL DIGITAL TELEPHONE SWITCHING SYSTEM
(approximate quantities for 2000,000 lines production)

Category of Integrated Circuits	QTY. used (no.'s)	Unit price US$	Total cost US$
C. TTL HIGH SPEED HCT series			
Type 1	1,678	0.126	211
2	1,678	0.126	211
3	5,034	0.120	604
4	4,195	0.120	503
5	1,678	0.126	211
6	1,678	0.126	211
7	1,678	0.126	211
8	1,678	0.250	420
9	4,195	0.200	839
10	1,678	0.250	420
11	1,678	0.750	1,259
12	2,517	0.250	629
13	1,678	0.380	638
14	1,678	0.300	503
15	6,712	0.250	1,678
16	20,975	0.260	5,454
17	1,678	0.350	587
18	67,120	0.225	15,102
19	1,678	0.200	336
20	1,678	0.200	336
21	8,390	0.135	1,133
22	4,195	0.210	881
23	30,204	0.400	12,082
24	12,585	0.650	8,180
25	4,195	0.250	1,049
26	6,712	0.250	1,678
27	1,678	0.250	420
28	16,780	0.225	3,776
29	58,730	0.225	13,214
30	6,712	0.420	2,819
31	16,780	0.750	12,585
32	4,195	3.600	15,102
33	6,712	2.800	18,794
34	25,170	0.620	15,605
total TTL HS HCT series	335,600	0.410	137,680

Table 4.6 (continued)

Typical Distribution of various types of IC's used IN A TYPICAL DIGITAL TELEPHONE SWITCHING SYSTEM
(approximate quantities for 2000,000 lines production)

Category of Integrated Circuits		QTY. used (no.'s)	Unit price US$	Total cost US$
D. TTL 7400 series				
Type	1	29,365	0.160	4,698
	2	8,390	0.160	1,342
	3	25,170	0.160	4,027
	4	1,678	0.400	671
	5	1,678	0.500	839
	6	6,712	0.155	1,040
	7	6,712	0.155	1,040
	8	1,678	1.500	2,517
	9	6,712	0.400	2,685
	10	3,356	1.500	5,034
total TTL 7400 series		91,451	0.261	23,895
E. VOLTAGE REGULATORS				
Type	1	54,535	0.180	9,816
	2	26,848	0.180	4,833
	3	62,925	0.180	11,327
	4	12,585	0.180	2,265
total V.R.'s		156,893	0.180	28,241
F. OP AMPS				
Type	1	168	0.590	99
	2	25,170	0.550	13,844
	3	25,170	0.400	10,068
	4	33,560	0.160	5,370
	5	18,458	0.120	2,215
	6	1,678	0.750	1,259
total OP AMPS		104,204	0.315	32,854
G. TIMERS				
Type	1	4,195	0.110	461
	2	2,517	0.240	604
	3	1,678	0.500	839
Timers		8,390	0.22[illegible]	1,905

Table 4.6(continued)

Typical Distribution of various types of IC's used IN A TYPICAL DIGITAL TELEPHONE SWITCHING SYSTEM

(approximate quantities for 2000,000 lines production)

Category of Integrated Circuits		QTY. used (no.'s)	Unit price US$	Total cost US$
H. INTERFACE CIRCUITS				
Type	1	12,585	0.275	3,461
	2	10,907	0.300	3,272
	3	1,678	2.000	3,356
	4	1,678	5.500	9,229
	5	1,678	0.700	1,175
	6	1,678	0.700	1,175
	7	16,780	0.500	8,390
	8	16,780	0.500	8,390
	9	1,678	0.200	336
	10	1,678	0.300	503
	11	1,678	5.000	8,390
total interface circuits		68,798	0.693	47,676
I. TELECOM CIRCUITS		12,585	1.350	16,990
J. MUPS				
Type	1	8,390	12.000	100,680
	2	4,195	3.400	14,263
	3	6,712	3.780	25,371
	4	5,034	3.200	16,109
	5	1,678	5.250	8,810
	6	25,170	4.300	108,231
	7	3,356	21.000	70,476
	8	1,678	36.000	60,408
	9	1,678	42.000	70,476
	10	839	20.000	16,780
Total MUPS		58,730	8.371	491,604
K. Microprocessors				
Type	1	1,678	3.800	6,376
	2	8,390	4.600	38,594
	3	3,356	2.700	9,061
	4	6,712	3.150	21,143
	5	20,975	5.000	104,875
	6	50,340	3.150	158,571
	7	6,712	47.000	315,464
	8	1,678	3.500	5,873
total micro-processors		99,841	6.610	659,957

Table 4.6 (continued)

Typical Distribution of various types of IC's used IN A TYPICAL DIGITAL TELEPHONE SWITCHING SYSTEM
(approximate quantities for 2000,000 lines production)

Category of Integrated Circuits		QTY. used (no.'s)	Unit price US$	Total cost US$
L. RAMS				
Type	1	5,034	2.000	10,068
	2	16,780	3.000	50,340
	3	16,780	8.000	134,240
	4	8,390	7.000	58,730
	5	1,678	3.000	5,034
	6	469,840	1.100	516,824
	7	2,517	3.000	7,551
	8	2,517	3.000	7,551
	9	6,712	5.500	36,916
	10	4,195	5.500	23,073
	11	29,365	5.500	161,508
Total RAMS		563,808	1.795	1,011,834
M. PROMS/EPROMS				
Type	1	3,356	7.000	23,492
	2	8,390	0.600	5,034
	3	1,678	5.100	8,558
	4	1,678	10.000	16,780
	5	16,780	2.400	40,272
	6	11,746	3.300	38,762
	7	8,390	2.400	20,136
	8	6,712	2.400	16,109
	9	6,712	2.400	16,109
	10	6,712	2.400	16,109
	11	6,712	38.000	255,056
	12	1,678	10.000	16,780
total PROMS & EPROMS		80,544	5.875	473,196

Table 4.6(continued)

Typical Distribution of various types of IC's used IN A TYPICAL DIGITAL TELEPHONE SWITCHING SYSTEM

(approximate quantities for 2000,000 lines production)

Category of Integrated Circuits		QTY. used (no.'s)	Unit price US$	Total cost US$
N. Other IC's				
Type	1	67,120	0.420	28,190
	2	5,034	4.200	21,143
	3	17,451	5.500	95,982
	4	6,712	5.000	33,560
	5	839	10.500	8,810
	6	83,900	0.270	22,653
	7	6,712	0.280	1,879
	8	20,975	3.000	62,925
	9	839	29.000	24,331
	10	1,678	0.500	839
	11	16,780	0.370	6,209
	12	839	1.000	839
	13	20,975	1.000	20,975
	14	16,780	1.000	16,780
	15	8,390	0.700	5,873
	16	25,170	1.500	37,755
Total		300,194	1.295	388,742

SUMMARY

	Type of IC	No of Types	Qty Used No.'s	Total Cost US$	Overall Average Unit Price US$
A.	TTL Fast	26	409,600	121,370	0.296
B.	TTL HS HC Series	55	2,109,246	453,362	0.215
C.	TTL HS HCT series	34	335,600	137,680	0.410
D.	TTL 7400 series	10	91,451	23,895	0.261
E	Voltage regulator	4	156,893	28,241	0.180
F	OP AMPS	6	104,204	32,855	0.315
G	Timers	3	8,390	1,905	0.227
H	Interface (CMOS)	11	68,798	47,672	0.693
I	Telecom circuits	1	12,585	16,998	1.351
J	MUPS	10	58,730	491,604	8.371
K	Microprocessors	8	99,841	659,957	6.610
L	RAMS	11	563,808	1,011,834	1.795
M	Proms/Eproms	12	80,544	473,196	5.875
N	Others	16	300,194	388,742	1.295
Total		207	4,399,884	3,889,310	0.884

Table 4.7

TYPICAL PRODUCTION
PLANT REQUIREMENTS FOR 200,000 & 500,000 LINES P.A.
OF A TYPICAL DIGITAL TELEPHONE SWITCHING SYSTEM
(FOR A MIX OF SMALL MEDIUM & LARGE EXCHANGES)
Based on pure assembly & testing operation

MACHINE/TESTER	Required for 200K no.	Required for 500K no.	Cost/ Unit US$	Total Cost for 200K US$	Total Cost for 500K US$
A. INCOMING INSPECTION					
1. RLC Meter	9	18	7,500	67,500	135,000
2. Device testers for					
a) Active discrete devices	8	14	15,000	120,000	210,000
b) Transformers	2	5	15,000	30,000	75,000
c) Relays	2	5	5,500	11,000	27,500
d) Hybrid Micro Circuits	3	6	1,300	3,900	7,800
e) IC's TTL & CMOS	7	16	600	4,200	9,600
f) IC's-Universal	1	1	60,000	60,000	60,000
g) Codec (P)	1	2	25,000	25,000	50,000
F)	2	2	1,500	3,000	3,000
h) LSI's	3	8	3,500	10,500	28,000
i) Memories	4	4	1,500	6,000	6,000
j) Crystals	2	3	7,000	14,000	21,000
k) Linear IC's	2	3	20,000	40,000	60,000
l) IC handlers	7	16	7,000	49,000	112,000
3. Miscellaneous	2	3	15,000	30,000	45,000
Total				474,100	849,900
B. Card Assembly-Kitting					
1. Lead Forming Machines					
a) IC Preforming Machines	2	3	3,000	6,000	9,000
b) Axial type comp. crop/ form machines	2	3	2,000	4,000	6,000
c) Radial type comp. Crop/ Form machines	2	3	2,000	4,000	6,000
d) Universal Comp Preparat-ion Machines	2	3	3,000	6,000	9,000
e) Radial super jig for (d)	2	3	1,000	2,000	3,000
2. Comp. Counting M/c's	2	3	1,000	2,000	3,000
3. Tape Dispensers	6	10	500	3,000	5,000
4. PCB Offset Marking M/c's	2	2	1,000	2,000	2,000
5. Others	Lot	Lot		3,000	5,000
Total				32,000	48,000

Table 4.7 (continued)

TYPICAL PRODUCTION
PLANT REQUIREMENTS FOR 200,000 & 500,000 LINES P.A.
OF A TYPICAL DIGITAL TELEPHONE SWITCHING SYSTEM
(FOR A MIX OF SMALL MEDIUM & LARGE EXCHANGES)
Based on pure assembly & testing operation
Based on pure assembly & testing operation

MACHINE/TESTER	Required for 200K no.	Required for 500K no.	Cost/ Unit US$	Total Cost for 200K US$	Total Cost for 500K US$
C. Card Assembly & Wave soldering					
1. Semi Auto Machines	30	38	20,000	600,000	760,000
2. Manual Stations	66	72	1,500	99,000	108,000
3. Conveyor belt systems per 10 stations	9	11	2,000	18,000	22,000
4. Loaded PCB Comparators	8	10	3,000	24,000	30,000
5. Vacuum Forming Machines	6	8	7,000	42,000	56,000
6. Wave Soldering Machines	2	2	15,000	30,000	30,000
7. Aquous cleaners	2	2	15,000	30,000	30,000
8. Main Lead Trimming M/c's	4	5	7,000	28,000	35,000
9. DI Water Plant	2	2	7,500	15,000	15,000
10.Rework Station	15	18	1,200	18,000	21,600
11.Others	lot	lot		22,000	31,400
Total				990,000	1,235,000
D. Final Card Assembly					
1. Automator Lever Press	3	5	200	600	1,000
2. Rivetting Gun	2	3	250	500	750
3. Insert Machine	1	2	200	200	400
4. Power Screw Drivers	5	8	200	1,000	1,600
5. Flat Cables/Connector crimps	1	2	150	150	300
6. Thermal strippers	2	3	100	200	300
7. Pneumatic vices	20	20	150	3,000	3,000
8. Manual Torque Screw drivers	2	2	50	100	100
9. Hot Air Blowers	2	2	100	200	200
10.Others	Lot	Lot		1,000	1,500
			Total	6,950	9,150

Table 4.7 (continued)

TYPICAL PRODUCTION
PLANT REQUIREMENTS FOR 200,000 & 500,000 LINES P.A.
OF A TYPICAL DIGITAL TELEPHONE SWITCHING SYSTEM
Based on pure assembly & testing operation

MACHINE/TESTER	Required for 200K no.	Required for 500K no.	Cost/ Unit US$	Total Cost for 200K US$	Total Cost for 500K US$
E. IN-PRODUCTION TESTING & SOFTWARE PROGRAMMING					
1. Dedicated H/W Tester	64	110	3,000	192,000	330,000
2. Logic Probes & Pulsers	35	50	725	25,375	36,250
3. Oscilloscopes	35	75	3,000	105,000	225,000
4. Multimeters	60	120	150	9,000	18,000
5. Gang Programmers & Eraser	3	3	7,000	21,000	21,000
6. Terminals	70	110	500	35,000	55,000
7. PSU's	30	60	300	9,000	18,000
8. BM Testers	9	18	10,000	90,000	180,000
9. CM Testers	1	2	10,000	10,000	20,000
10.BM Soak Testers	3	4	50,000	150,000	200,000
11.Multi BM Soak Testers	1	2	50,000	50,000	100,000
12.MICE	8	16	7,000	56,000	112,000
13.MDS	1	1	30,000	30,000	30,000
14.Rework Stations	6	12	1,500	9,000	18,000
15.IBM PC's	100	160	1,200	120,000	192,000
16.IBM PC/XT's	18	36	1,500	27,000	54,000
17.IBM PC/AT's	16	26	4,000	64,000	104,000
18.132 column printers	22	44	800	17,600	35,200
19.80 column printers	22	36	400	8,800	14,400
20.CAD stations & accessorie	3	6	8,000	24,000	48,000
21.IBM PC Software	1	1	5,000	5,000	5,000
22.Micro Vax II cluster or equivalent	2	5	100,000	200,000	500,000
23.Micro Vax accessories	2	5	12,000	24,000	60,000
24.Micro VAX Software	1	1	75,000	75,000	75,000
25.Televideo systems	6	6	20,000	120,000	120,000
26.UPS (50 KVA)	1	1	30,000	30,000	30,000
27.Miscellaneous (set)	1	1	100,000	100,000	100,000
Total				1,606,775	2,700,850

Table 4.7 (continued)

TYPICAL PRODUCTION
PLANT REQUIREMENTS FOR 200,000 & 500,000 LINES P.A.
OF A TYPICAL DIGITAL TELEPHONE SWITCHING SYSTEM
(FOR A MIX OF SMALL MEDIUM & LARGE EXCHANGES)

	Based on pure assembly & testing operation				
	Required for			Total Cost for	
MACHINE/TESTER	200K no.	500K no.	Cost/ Unit US$	200K US$	500K US$
F. Rack Assembly kitting					
1. Power cable cutter	1	1	250	250	250
2. Pressfit inserting M/c's	1	2	1,000	1,000	2,000
3. Insertion force controlle	1	1	500	500	500
4. Retention force contoller		1	500	0	500
5. Connector repairing tool set	1	1	500	500	500
6. Sleeve marking machine	1	1	250	250	250
7. Wire prefeed system	3	5	250	750	1,250
8. Auto twisted pair cut/ strip machines	1	1	500	500	500
9. Crimping tool	1	1	100	100	100
10. Crimping jaws	1	1	100	100	100
11. Auto feeding crimping M/c	1	1	1,000	1,000	1,000
12. Hot air blower Gun	2	2	250	500	500
13. Others	Lot			2,000	4,000
			Total	7,450	11,450
G. Final Assembly & Wire wrapping					
1. Power screw drivers of sorts	6	10	150	900	1,500
2. Automator Lever presses	2	2	200	400	400
3. Torque control device	1	2	250	250	500
4. Rivetting gun	1	2	250	250	500
5. Soldering gun	1	2	250	250	500
6. Torque screwdrivers of sorts	2	4	150	300	600
7. Air controlled wrapping guns	20	40	100	2,000	4,000
8. Cable set testing machine	1	1	350	350	350
9. Wrapping Pull off tester	1	1	200	200	200
10. Test Unit for Cords & plugs	1	1	400	400	400
11. Rack trolleys	10	25	400	4,000	10,000
12. Others	Lot	Lot		2,000	5,000
Total				11,300	23,950

Table 4.7 (conitnued)

TYPICAL PRODUCTION
PLANT REQUIREMENTS FOR 200,000 & 500,000 LINES P.A.
OF A TYPICAL DIGITAL TELEPHONE SWITCHING SYSTEM
(FOR A MIX OF SMALL MEDIUM & LARGE EXCHANGES)

Based on pure assembly & testing operation

MACHINE/TESTER	Required for 200K no.	Required for 500K no.	Cost/ Unit US$	Total Cost for 200K US$	Total Cost for 500K US$
H. System integration, Simulation Tests, & Heat Runs of Critical Modules/blocks					
1. System Integration Platforms	2	5	100,000	200,000	500,000
2. Trunk Call generators	2	5	10,000	20,000	50,000
3. Subscriber Call generators	2	5	10,000	20,000	50,000
4. Burn-in equipment	2	3	10,000	20,000	30,000
5. Interface cables & Misc Equipment	lot	lot		20,000	50,000
6. Test equipment, software, p.c.'s, printers etc	2	3	100,000	200,000	300,000
Total				480,000	980,000

I. INFRASTRUCTURE

	Required for 200 K Area Sq.m. (000)	Required for 500 K Area Sq.m. (000)	Cost/ Sq.m. US$	Total cost for 200 K US$	Total cost for 500 K US$
1. Land	50	50	10	500,000	500,000
2. Building	12	20	100	1,200,000	2,000,000
3. Electrical Instn	12	20	20	240,000	400,000
4. Environmental Control	12	20	20	240,000	400,000
5. Compressed Air distribution System		lot		100,000	150,000
lot 100,000 150,000					
6. Water Supply		lot		50,000	50,000
7. Others including handling and transport equipment, overhead cranes etc		lot		200,000	300,000
		Total		2,530,000	3,800,000

Table 4.8

TYPICAL PRODUCTION
PLANT REQUIREMENTS FOR 200,000 & 500,000 LINES P.A.
OF A TYPICAL DIGITAL TELEPHONE SWITCHING SYSTEM
(FOR A MIX OF SMALL MEDIUM & LARGE EXCHANGES)
Based on pure assembly & testing basis

INVESTMENT SUMMARY

	Total Investment Cost for 200K Lines P.A. US$	Total Investment Cost for 500K Lines P.A. US$
Machines & Testers		
A. Incoming Inspection	474,100	849,900
B. Card Assembly-Kitting	32,000	48,000
C. Card Assembly & Wave Soldering	990,000	1,235,000
D. Final Card Assembly	6,950	9,150
E. In-Production Testing & Software & Data Generation	1,606,775	2,700,850
F. Rack Assembly Kitting	7,450	11,450
G. Final Assembly & Wire Wrapping	11,300	23,950
H. System Integration, Simulation tests etc	480,000	980,000
J. Total Machines & Testers (A to H)	3,608,575	5,858,300
K. Incidental expenses, Erection & Test runs @ 40% of J	800,000	1,200,000
I. Infrastructure, land, buildings etc	2,530,000	3,800,000
Grand Total (J+K+I)	6,938,575	10,858,300

Notes:

1. Above assumes international competitive prices with no local import duties and other tariffs.

2. For infrastructure comparatively lower costs prevailing in developing countries have been assumed.

3. Incidental & erection expenses include about 20% on account of freight, and 20% on account of erection, installation and trial runs latter mostly carried out by local staff under supervision of suppliers' engineers.

Table 4.9

TYPICAL MANPOWER REQUIREMENTS FOR PRODUCTION PLANT FOR 200,000 & 500,000 LINES P.A. OF A TYPICAL DIGITAL TELEPHONE SWITCHING SYSTEM (FOR A MIX OF SMALL MEDIUM & LARGE EXCHANGES)

Based on pure assembly & testing basis

A: IN A DEVELOPED COUNTRY

	Manpower Required for 200K lines no.	Manpower Required for 500K lines no.	Cost/ Unit US$ (000)	Total Cost p.a. for 200K Lines US$	Total Cost p.a. for 500K Lines US$
1.Managing Director	1	1	100	100,000	100,000
2.Managers	3	5	60	180,000	300,000
3.Engineers	30	50	45	1,350,000	2,250,000
4.Testers & Supervisors	40	70	35	1,400,000	2,450,000
5.Skilled operatives	150	275	30	4,500,000	8,250,000
6.Mat'l Handlers	10	20	25	250,000	500,000
7.Sales	5	8	45	225,000	360,000
8.Buyers	5	8	35	175,000	280,000
9.Accounts	8	12	35	280,000	420,000
Total	251	448		8,460,000	14,910,000
Per line				42.30	29.82

B: IN A DEVELOPING COUNTRY e.g. INDIA

	Manpower Required for 200K lines no.	Manpower Required for 500K lines no.	Cost/ Unit US$ (000)	Total Cost p.a. for 200K Lines US$	Total Cost p.a. for 500K Lines US$
1.Managing Director	1	1	12	12,000	12,000
2.Managers	3	5	8	24,000	40,000
3.Engineers	30	50	6	180,000	300,000
4.Testers & Supervisors	40	70	3	120,000	210,000
5.Skilled operatives	150	275	2	300,000	550,000
6.Mat'l Handlers	10	20	1	10,000	20,000
7.Sales	5	8	5	25,000	40,000
8.Buyers	5	8	4	20,000	32,000
9.Accounts	8	12	4	32,000	48,000
Total	251	448		723,000	1,252,000
Per line				3.62	2.50

CHAPTER 5

JELLY FILLED COPPER CONDUCTOR TELEPHONE CABLES

5.1 Introduction:

5.1.1 The analysis in chapter 3 tables 3.2 to 3.5, indicates that the contribution of the subscriber line to the average overall per line cost of PSTN is substantial. In case of high and medium density areas it is only second to the total cost of switching nodes. The subscriber line contributes rouhgly 20 to 22% to the overall costs in high density areas and about 30 to 31% in case of medium density areas.

5.1.2 Table 3.1 gives a somewhat more detailed break up of the elements going into subscriber line costs. It will be seen that in case of high density areas distribution and primary cables are estimated to account 13.5% out of about the 21% of the total share of subscriber line. In case of medium density areas they account for about 21% out of roughly 31% of the total share. In modern practice, both these cables are usually of the jelly filled type, though large quantities of older type paper insulated lead sheath cables are still working.

The reduction in cost of jelly filled cables is therefore of considerable importance.

5.2 Construction of jelly filled telephone cables

Fig 5.1 illustrates the construction of a typical jelly-filled polyethylene insulated unit twin telephone cable.

5.2.1 Conductors

The low resistance conductors for telephone cables are predominantly of solid copper, round in cross section and usually of 0.4, 0.5, 0.63 and sometimes of 0.9 mm diameter. They are drawn to required diameter from annealed bright copper rods.

5.2.2 Conductor insulation

Each conductor is individually insulated with suitably coloured (for identification) solid or foam polyethylene plastic insulation of uniform thickness to ensure high insulation.

5.2.3 Twinning

Two insulated conductors are twisted together with a uniform lay to form a pair. The length of the lay of any pair has to be different from the lay of the adjacent pairs to reduce cross talk to the minimum.

5.2.4 **Formation of core**

5.2.4.1 A number of pairs are arranged together to form a circular core. In cables of 5, 10 and 20 pairs, the required number of twisted insulated pairs are stranded together to form the circular core.

5.2.4.2 In 50 and 100 pair cables, 10 and 20 twisted insulated pairs are stranded together to form units of 10 and 20 pairs. Each unit is suitably wrapped in a polyester, polyethylene or polypropylene tape in an open helical lapping. The tapes are suitably coloured to identify the units. 5 units of 10 and 20 pairs each are then suitably assembled together to give the circular core of the 50 and 100 pair cables repectively.

5.2.4.3 In 200, 300 and 400 pair cables, 5 units of 10 pairs each are stranded together and wrapped in a suitably coloured plastic lapping to form a super unit of 50 pairs. The requisite number of these super units are then assembled together to give the 200, 300 and 400 pair cable cores.

5.2.4.4 In cables of 600 pair or higher size, 5 units of 20 pairs each are stranded together with an additional spare pair added and wrapped in suitable coloured plastic lapping to give super units of 100 pairs each, appropriate number of which are assembled together to give the core for required sized cables

5.2.4.5 Because of this practice of forming 10, 20, 50 and 100 pair units to give higher sizes of cables, such cables are known as 'Unit twin cables'. The formation of the units and their identification by coloured lapping is of considerable assistance in the field in jointing and branching cables as needed.

5.2.5 **Petrolium jelly**

The intersticial space of the cable core formed as above is filled with a suitable water resistant compound, main constituent of which is petrolium jelly. The main requirements of the compound are high resistance to water penetration, neutrality to copper conductor, polyethylene insulation, sheath and lapping tapes, and poly aluminium tape, non obscuring of insulating compound colours, freedom from unpleasant odour and any toxic or dermatic hazards, and ready wipeability from the insulated conductors for reliable jointing.

5.2.6 **Poly-Al screen**

To hold the petroleum jelly in place, the filled core is wrapped either longitudinally or in a closed helical lap with either a non-hygroscopic jelly impregnated paper or plastic tape.

The core is then wrapped either longitudinally or in a closed helical lap with a Poly-Al (aluminium coated with polythene/copolymer on both sides) tape to provide electro-magnetic screening/ shielding. To be effective it must be electrically continuous throughout the length of the cable.

5.2.7 **Sheath**

Immediately over the Poly-Al screen, a black polyethylene sheath of appropriate thickness is extruded to provide mechanical protection and a moisture proof barrier.

Above covers the construction of the basic jelly-filled, polyethylene insulated unit twin cables for use in cable ducts.
Chapter 5 page 3/11

5.2.8 **Steel Tape Armouring**

In very low density and rural areas, cables are often laid directly buried. In such cases it is usual to provide additional protection against mechanical damage, by way of two helical wrappings of galvanized steel tape, first one with a gap and the second evenly covering the gap. As a protection against damage during armouring process two close lappings of waterproof cotton or plastic tape are applied over the sheathed core before armouring. The armoured cable is finally provided a polyethylene jacket or sheath.

5.2.9 **Cable lengths**

Cables are supplied on drums in suitable lengths convenient for handling. However in the field it is necessary to have a continuous pair from the exchange to the subscriber apparatus. For this purpose the individual cable lengths are laid in the ducts or directly buried end to end. The ends of the cable pairs are suitably joined (earlier with twist jointing, later by soldering and now using in-length connectors). The joints are enclosed in suitable water tight sleeves or closures.

5.3 **Cable prices and suppliers**

Table 5.2 gives the international prices for a few typical sizes of cables based on information obtained regarding certain global tenders. Cables are being manufactured by a very large number of companies internationally. Most of the recognized manufacturers of telecommunication equipment also manufacture telephone cables. Besides, a number of companies specialize in production of cables both for the telecommunication and power sectors, and still others produce only telecommunications cables.

5.4 **Jelly filled cable production and inputs required**

Production of jelly-filled cables is a comparatively simple, and fairly well standardized process.

Table 5.3 gives a list of the important raw materials, their unit prices and quantities required for an annual cable production of 500,000 conductor Km in 4500 Km of sheath.

Chart 5.4 gives the basic process flow for the cable production.

Table 5.5 gives the basic machinery,tools and testers for a jelly-filled cable factory for an annual production as indicated above. Also indicated are the basic infrastructural requirements and an estimate of total investment.

Table 5.6 gives the manpower requirements for the above factory and likely annual manpower costs in a developed and a developing country.

Annexed:

Figure 5.1: Typical construction of polythene insulated jelly filled cable

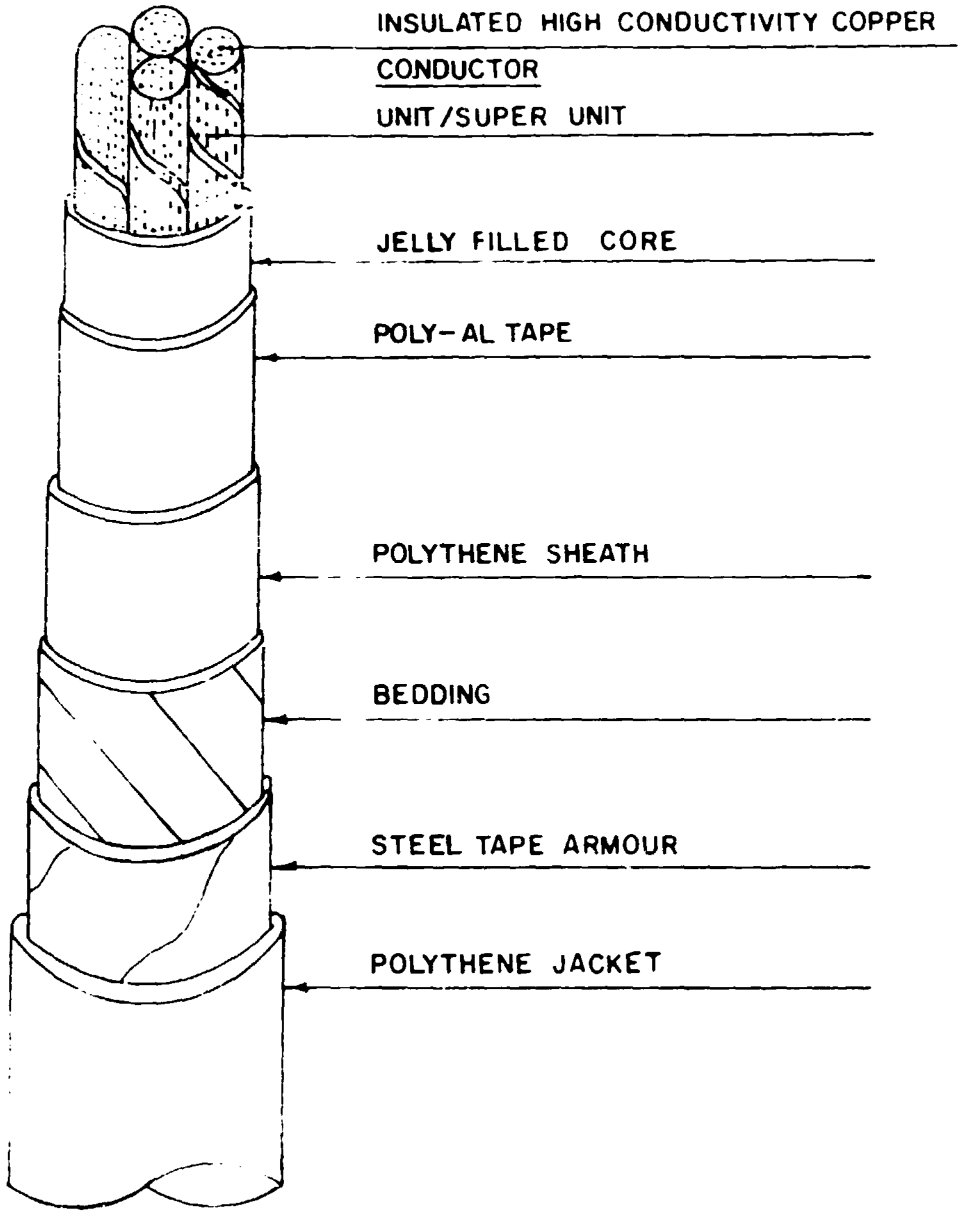
Figure 5.2: Typical International prices for jelly filled cables of various sizes.

Figure 5.3: Typical Raw materials required for production of 500,000 conductor Km in 4.500 Sheath Km of armoured jelly filled cables

Figure 5.4: Typical process flow chart for production of Jelly filled cables

Table 5.5: Typical machinery, tools and testers etc. required for an annual production of about 500,000 conductor Km in 4,500 sheath Km of jelly filled cables

Table 5.6: Typical manpower requirements for an annual production of 500,00 conductor Km in 4,500 sheath Km of jelly filled cables



TYPICAL CONSTRUCTION OF POLYTHENE INSULATED JELLY FILLED CABLE

FIG 5.1

Table 5.2

Typical International Prices for JELLY-Filled Telephone Cables

Sl. No.	Particulars of cables Cond. Diam. in mm	No. Of Prs.	Unit Price US$/Km
1.	0.4	20	914
2.	0.4	400	9,050
3.	0.4	800	17,500
4.	0.4	1000	20,500
5.	0.4	1800	35,700
6.	0.5	400	13,800
7.	0.5	800	18,200
8.	0.5	1000	22,000
9.	0.5	1800	48,400
10.	0.6	50	3,170

Note : Above prices are based on quotations in certain international bids during 1990-91 and are subject to significant variaions on the basis of international copper prices.

Table 5.3

Raw materials required for production of About 500,000 conductor Km in 4500 sheath Km of jelly filled cables

Sl. No.	Particulars	Qty Reqd M.T.	Unit Price US$/M.T.	Total Cost US$
1.	Annealed Bright Copper Rods	930	3,000	2,790,000
2.	High Density Polyethylene	360	1,500	540,000
3.	Colour Master Binder	18	10,000	180,000
4.	Colour Binder	5	3,500	17,500
5.	Filling Compound	375	1,000	375,000
6.	Polyester Film(core wrap)	31	4,000	124,000
7.	Aluminium Laminate(Poly-Al)	170	3,000	510,000
8.	Waterproof insulation tape	30	3,000	90,000
9.	Low Density Polyethelene(LDPE)	1,000	2,000	2,000,000
10.	LDPE Tape	112	2,000	224,000
11.	Galvanized steel tape	1,900	700	1,330,000
12.	Flooding compound	40	1,500	60,000
Total				8,240,500

Above requirements are based on following product mix.

Cable Size No. of Conductor Pair	Guage	Sheath Length Km.	Conductor Km.
20	0.5 mm	250	10,000
50	0.5 mm	4,200	420,000
400	0.5 mm	30	24,000
600	0.5 mm	40	48,000
	Total	4,520	502,000

CHART 5-4

PROCESS FLOW CHART FOR PRODUCTION OF JELLY FILLED CABLES

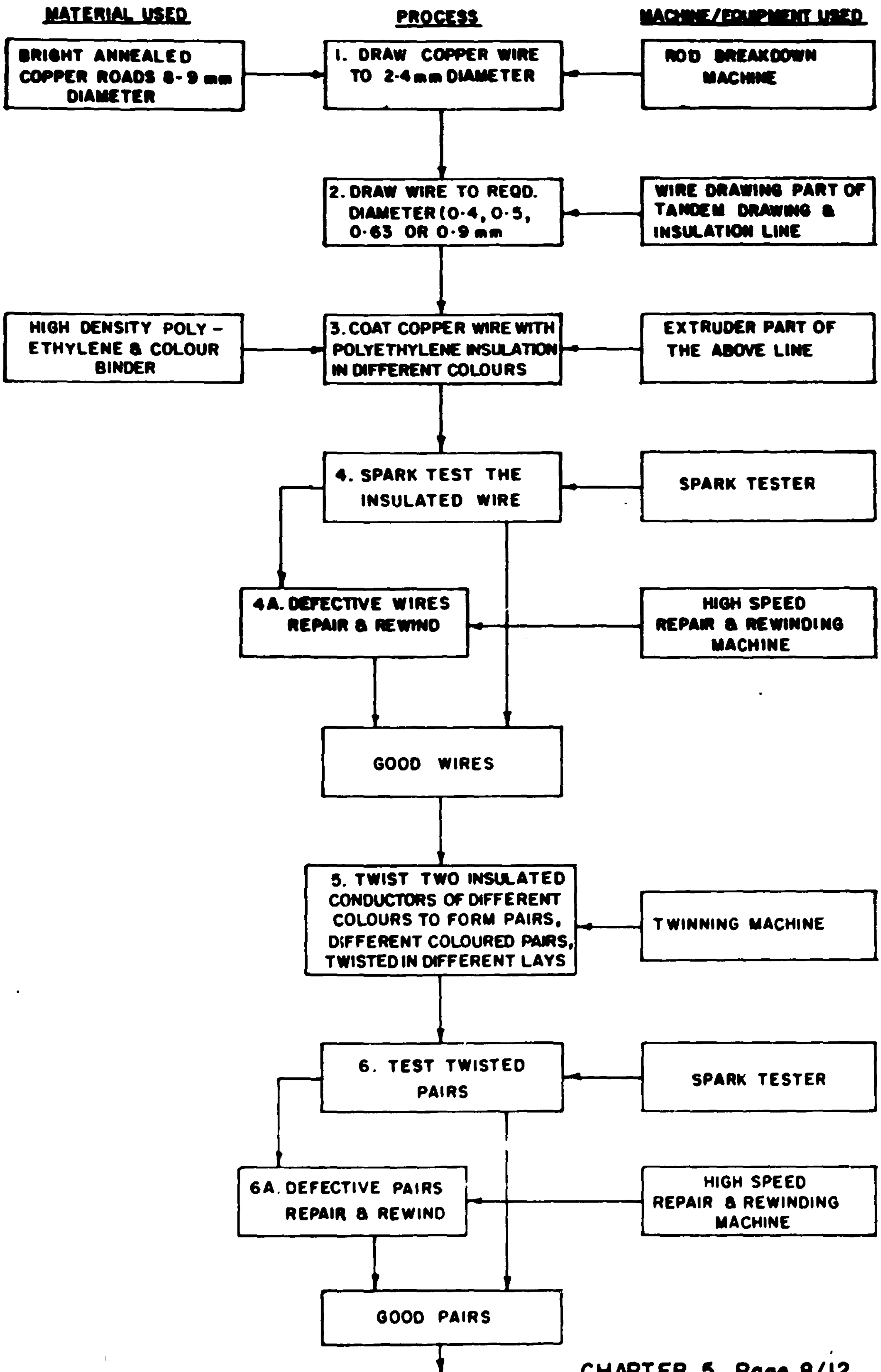


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CHART 5·4 (CONTINUED)

PROCESS FLOW CHART FOR PRODUCTION OF JELLY FILLED CABLES

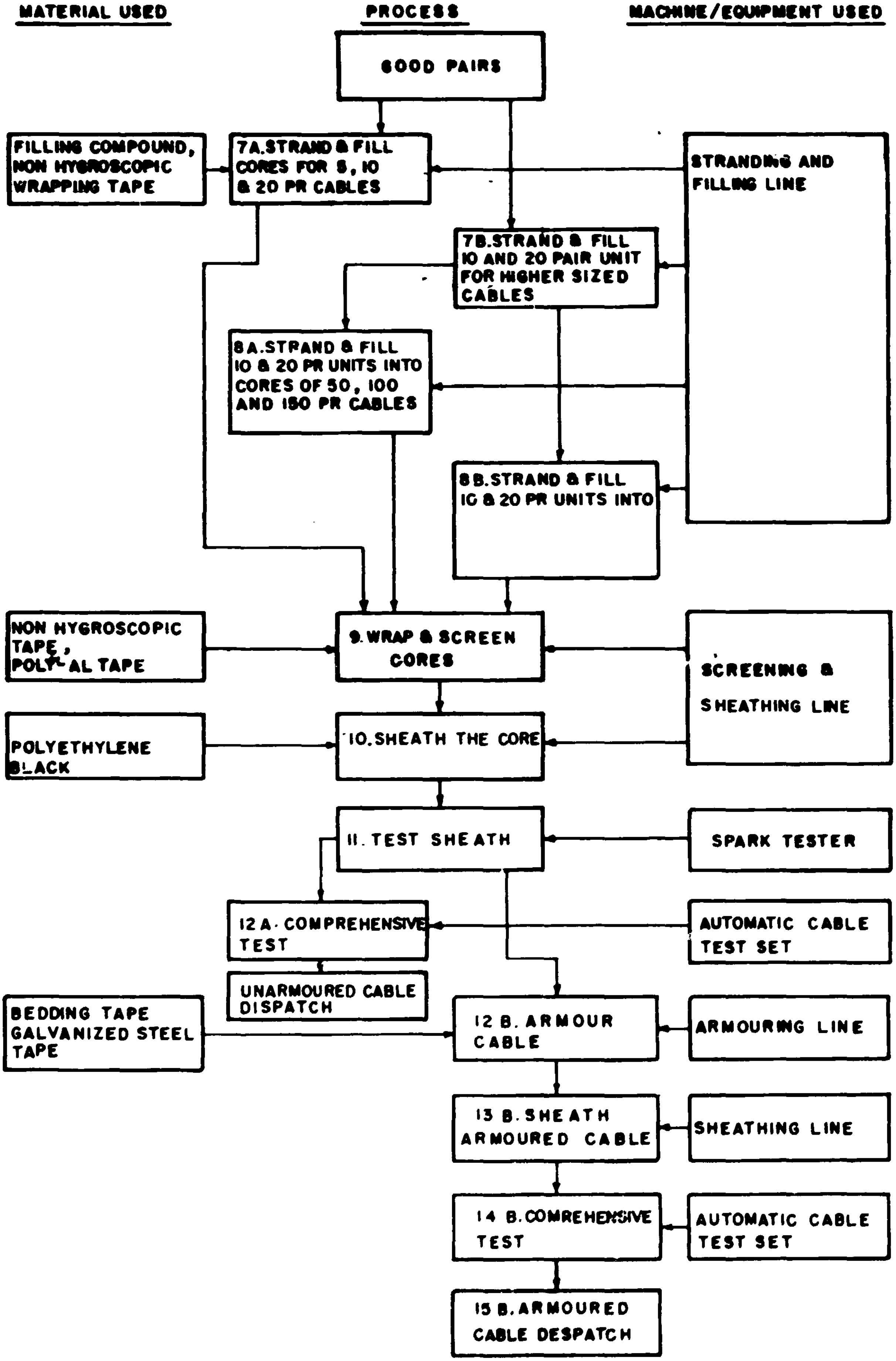


Table 5.5

Machinery, Tools & Testers required for production of about 500,000 conductor Km in 4500 sheath Km of jelly filled cables per annum

No.	Particulars	Qty Reqd no.'s	Unit Price US$/Pc.	Total Cost US$
A:	Machines			
1.	Rod Breakdown Machine	1	100,000	100,000
2.	High Speed Wire Drawing Machines	2	100,000	200,000
3.	Tandem Insulating Machines	2	600,000	1,200,000
4.	Twinning Machines with Pay Offs	3	110,000	330,000
5.	High Speed repair & rewinding Machine	1	100,000	100,000
6.	Stranding (Drum twist)M/c	1	950,000	950,000
7.	Sheathing, filling & Jacketing M/c	1	685,600	685,600
8.	Jelly Filling equipment	1	500,000	500,000
7.	Cable repair line	1	100,000	100,000
8	Armouring Machine	1	150,000	150,000
	Total A: Machines			4,315,600
B:	Testing equipment			
1.	Automatic Cable test centre	1	330,000	330,000
2.	Resistance Unbalance Meter	1	3,000	3,000
3.	DC Resistance Bridge Meter	1	12,000	12,000
4.	Insulation Tester	1	1,000	1,000
5.	Multimeters	2	1,000	2,000
6.	Thermal Analyser	1	30,000	30,000
7.	Optical Micrometer	1	7,000	7,000
8.	Extrusion Plastometer	1	7,500	7,500
9.	Density Gradient Meter	1	5,000	5,000
10.	ECSR Notching Jig with Accessories	1	4,000	4,000
	Total B: Testing Equipment			401,500

Table 5.5(continued)

Machinery,Tools & Testers required for production of About 500,000 conductor Km in 4500 sheath Km of jelly filled cables per annum

No.	Particulars	Qty Reqd no.'s	Unit Price US$/Pc.	Total Cost US$
C:	**Miscellaneous equipment**			
1.	Fork Lift Trucks	2	10,000	20,000
2.	Mobile Cranes	2	10,000	20,000
3.	Process drums(Assorted sizes)	1000	Various	50,000
4.	Mobile welder	1	5,000	5,000
5.	Air Compressor	1	10,000	10,000
6.	Weigh Bridge	1	3,000	3,000
7.	Misc(bins,trolleys,reels etc)	Lot	100,000	100,000
	Total C: Miscellaneous Equipment			208,000

D: INFRASTRUCTURE

No.	Particulars	Area Sq. M.	Unit cost US$/Sq M	Total Cost US$
1.	Land	100,000	1	100,000
2.	Building	10,000	120	1,200,000
3.	Electric Power	10,000	25	250,000
4.	Environmental control	10,000	40	400,000
5.	Water Supply	10,000	10	100,000
6.	Misc(transport,Furniture etc)	Lot		250,000
	Total D: Infrastructure			2,300,000

SUMMARY OF LIKELY INVESTMENT

A: Machines	4,315,600
B: Testers etc	401,500
C: Misc. Equipment	208,000
D: Infrastructure	2,300,000
E: Handling,Installation & Erection and trial runs @ 40 of A to C	1,970,040
Total estimated investment	9,195,140

Notes:
1. All prices are estimates of International Prices FOB country of origin; no frieght,insurance,local taxes etc have been included.
2. Frieght, insurance, installation & trial runs under supervision of suppliers have been included under E.

Table 5.6

Manpower required for production of About 500,000 conductor Km in 4500 sheath Km of jelly filled cables per annum

			All inclusive Annual Personnel Costs			
			Developed Country		Developing Country	
Sl.no.	Particulars	No. Reqd US$ no.	Unit Cost US$ (000)	Total Cost US$ (000)	Unit Codt US$ (000)	Total Cost US$ (000)
	Wholetime regular personnel					
1.	Managing Director	1	100	100	12	12
2.	Managers	4	60	240	8	32
3.	Supervisors & Testers	10	35	350	3	30
4.	Operatives-Highly skilled	30	30	900	2.5	75
5.	Operatives Skilled	30	25	750	2	60
6.	Handlers	30	25	750	2	60
7.	Sales	5	45	225	5	25
8.	Accounts	8	35	280	4	32
9.	Buyers	5	35	175	4	20
10.	Others	10	30	300	2.5	25
	Total Annual cost	133		4,070		371

Chapter 6

Transimission systems

6.1 Introduction

6.1.1 The analysis in chapter 3 tables 3.2 to 3.5, indicates that transmission systems used primarily for inter switching node trunks, also constitute a substantial element in the overall cost of the PSTN. They rank after Switching nodes and subscriber line components in case of High and Medium density areas with 16.3 and 14.9 % share in the overall network costs, predominate in case of low density areas with a share of about 60%. In very low density areas, they can also be used, as a trade off, to provide substantial part of the subscriber line to serve the subscribers from a more central point and reduce the cost of switching and that of trunks between the subscriber and the first transit exchanges.

6.1.2 Unlike switching systems and subscriber line cables, there is a very wide variety of transmission systems in use and being produced worldwide. This is inherent in their very function. Transmission systems are used to provide links between switching nodes over diverse geographical terrain. They are used to provide trunks of various lengths from as low as one or two kilometers or sometimes even less to a few thousand kilometers half way around the globe. They are used to provide from a few circuits from a small rural exchange to its parent transit exchange, to tens of thousands between large transit exchanges serving large predominantly urban communities. Naturally, over the years many different systems have developed using different media, and technologies, each optimised for a particular application.

6.1.3 Initially the trunks were built on open wire lines with bare conductors of copper slung on insulators fixed on poles. Each pair of conductors provided a single circuit. From the beginning, to reduce costs, attempts were made to derive larger number of circuits from the physical pairs. As a first step, three circuits were derived from two pairs of wires using the phantom circuit concept. With the advent of electronics, multiplexing on the open wire lines was evolved. Due to cross talk and noise considerations only a few circuits could be derived. The normal practical maximum was about 16 (12+3+1). Open wire lines were also subject to serious damage and deterioration of performance from weather, storms etc. An effort was made to use underground cables. Certain carrier systems giving upto a maximum of about 60 circuits on a few test selected pairs in special quad cables became feasible.

6.1.4 A real break through came with the development of coaxial cables on the one hand and radio transmission on the other. With the coaxial cables, multiplexing upto a few thousand circuits on a pair of coaxial tubes became feasible. In case of radio, initially,with the development of H.F. systems, it became possible to have direct global communication. Later, with the development of systems in higher frequency ranges multiplexing of a large number of circuits became practical, capacity generally matching what had become feasible on coaxial cables. These were all based on the analog frequency division multiplexing. During the late 40's. and 50's and 60's a very large number of coaxial cable systems in the 4. and 12 Mhz bands giving 960 and 2700 channels were installed world wide and are working satisfactorily. Similarly radio relay systems of various capacities in the VHF. UHF and Microwave bands have been installed during late 50's uptill early 70's.

6.1.5 The digital technology came to transmission systems in late 50's in the form of 24 and 30 channel 2Mb/s PCM systems for junction working over test selected pairs in symmetrical cables. This was a major break through in bringing down the costs and improving the quality of junctions within large urban networks. Eventually it led to the development of the much more powerful digital systems both for transmission and switching. The development of digital switching has already been considered in chapter 4. In transmission. higher order multiplex systems of 8. 34. 140. and 565 Mb/s to give 30. 120. 480. 1920. and 7680 channels have been developed to work initially on coaxial cables and later. on optical fibre cables. Digital systems upto 140 Mb/s have also been used effectively for radio transmission systems. For the optical fibre applications even higher capacity systems of 2.26 Gb/s with a capacity of over 30.000 channels have been developed.

6.1.6 The advent of sputniks and satellites. brought about another major breakthrough in development of radio based transmission systems. The establishment of mircowave radio repeaters in space enabled very large coverage and freed the transmission systems from the problems of distances. earth's curvature and terrain. Satellite based systems provide from one to thousands of circuits from almost any point to any other point on the earth either direct or in combination with terrestrial media. While the systems intially were analog. digital systems are coming more and more into use.

6.1.7 A further development of special signficance has been the concept of sharing of radio channels on demand assignment basis. The concept has been applied succesfully to provide service economically to remote areas with low traffic. through Multi Access Radio relay systems. initially analog and later digital. The concept has been applied usefully to satellite based channels also. The concept has also led to developement of an economic mobile service in the form of cellular systems. bringing closer to fulfillment the dream of every telecommunication engineer of development of a personal pocket telephone for every one.

6.2 The more important and cost effective transmission systems working and being produced:

For the multi-channel application for inter node trunks.digital technology has now been universally adopted it is cost effective and gives much better quality and reliability than analog systems on any media. be they coaxial cables. optical fibres or radio systems. Among the media the choice depends to a large extent on the specific situation and application

6.2.1 Optical fibre systems

For new installations, transmission systems on optical fibres are generally most cost effective, particularly in normal flat terrain. For optical fibre applications, digital systems are available in 2Mb/s, 8Mb/s, 34 Mb/s, 140 Mb/s and 565 Mb/s giving 30, 120, 480, 1920 and 7680 voice/data channels of 64 Kb/s each. Very large number of these systems both land based and underwater, latter for inter-continental traffic, are being installed. 2.26 Gb/s systems capable of giving over 30,000 channels on a single pair of fibres, are also being installed in a few developed countries. Even higher order systems are under development.

6.2.2 Coaxial cable Systems

By and large no new coaxial cables are being laid. However, in situations where spare tubes already exist, or where it is intended to replace the existing analog coaxial cable systems, use of digital systems on the existing tubes provides a cost effective alternative to building up an entirely new infrastructure whether optical fibre or radio.

6.2.3 Terrestrial Radio systems

Augmentaion and upgradation of existing Radio based systems by installing digital systems using the existing infrastructure like towers and antenna is again cost effective compared to building up a totally new infrastructure even for optical fibre cables. Radio based systems, both terrestrial and satellite, also have an edge, even for new installations, in certain terrains and for certain applications, e.g., where very long distances are involved or there are features like high mountains or oceans to be crossed.

For radio relay applications, digital systems are available upto 140 Mb/s. The smaller capacity ones are working in the VHF and UHF bands while the larger capacity ones e.g. the 34 Mb/s and 140 Mb/s in the microwave range. The smaller capacity ones are of particular interest to developing countries, since they are specially cost effective for low density applications.

6.2.4 Satellite based radiosystems

Satellite based systems have proved very cost effective to provide trunks over large distances and to link remote areas with low traffic or difficult geographical terrain. Satellite based systems using the internationally owned Intelsat satellites are being used for bulk of the intercontinental traffic. They are also being used effectively for maritime mobile service using another group of internationally owned Inmarsat Satellites. Satellite based systems have also been used very effectively by a number of geographically spread out developing coutries to provide inter transit trunks and to link remote areas, and islands, either through their exclusive national satellites, or through regionally owned multi national satellites or through circuits or transponders hired from the Intelast. While bulk of the existing systems are analog, digital technology is now being increasingly adopted on satellite based systems also.

6.2.5 Special radio based systems for subscriber line application

Single channel radio systems in VHF range have been found useful for providing a few remote subscriber connections. from an exchange. However, for a larger number of connections spread over in a well defined area. demand assignment multi access systems. both analog and digital are more cost effective and are being installed in many countries. Cellular radio system is a special application of multi access systems specially designed and optimised for mobile and roaming service. Some developing countries. have effectively used the cellular radio/switching systems effectively for the pfovision of subscriber lines in rural areas in combinaion with mobile service. Demand assignment satellite based radio systems have also proved cost effective to provide subscriber connections in remote areas and have been used in mountaneous regions. islands and large plantation areas.

6.3 Manufacturers and suppliers of transmission systems:

Almost all the world's leading manufacturers of telecommunications equipment have developed and are manufacturing and supplying the entire range of transmission equipment. In addition many other firms. large and small. who do not produce other items of telecommunication equipment like switching. telephone instruments etc.. have also developed and produce transmission equipment. Annexure 6.1 gives an indicative non- comprehensive list of various producers of different types of transmission equipment. The list is largely based on the catalogue of exhibitors at Telecom 87.

6.4 Description, international prices and essential components going into assembly level production of typical transmission systems.

As indicated above a very large number of transmission systems of various capacities for different applications are being produced and installed. It is not possible to cover even typical systems of each type in this report. Only a few systems have been selected for discussion in this report. A generalised description of these systems follows in the following chapters. along with an approximate idea of their international prices and the essential components going into their production :

- Chapter 7: A typical 140 Mb/s optical fibre system
- Chapter 8: A typical 8 Mb/s digital radio system

Since the optical fibre cables are essential for optical fibre transmission systems which are of special interest to developing countries. because of their cost effectiveness for new installations. coupled with the potential for high reliability and quality of service, they have also been taken up in chapter 9 for a more detailed treatment

6.5 **Infrastructure by way of plant and machinery for production of transmission systems**

The infrastructure required by way of plant and machinery for assembly level production from bought out components and subsystems, for almost the entire range of electronic equipment particularly the transmission systems is almost identical. What differs are the set up and instruments required for the testing of different systems.

The basic common infrastructure consists of arrangements for procurement of the different types of components, their testing and preparation and kitting for loading on PCB's; automatic, semi-automatic or manual stations for loading the PCB's; comparator jigs for loaded PCB's; facilities for wave soldering, and cleaning of the soldered PCB's; visual and in-circuit testing of the PCB's and their repair when needed; and certain basic test facilities. These are listed for a medium sized operation in table 6.2.

The special test facilities call for test set ups for the detailed functional tests on various functional modules and the integrated systems. For reliability it is desirable that the testing is automatic and microprocessor based with test results displayed on suitable display panels, stored or made available as print outs as needed.

Annexed:

Annex 6.1: A partial list of manufacturers of Transmission equipment

Annex 6.2: A typical list of plant and machinery for production of transmission equipment

ANNEX 6.1

A Partial list of manufacturers of different types of Telecommunication Transmission Systems

Name of Manufacturer	Country
1 ABC Teleinformatica S/A	Brazil
2 Alcatel CIT	France
3 Amalgamated Wireless (Australasia)	Australia
4 Andrew Corp	UK
5 ANT Nachrichtetechnik GmbH	Germany
6 AT&T	USA
7 AT&T & Philips	Netherlands
8 Bharat Electronics Ltd	India
9 BTM	Belgium
10 Budavox Telecommunication Co	Hungary
11 Dateno	France
12 Ericsson	Sweden
13 Fujitsu Ltd	Japan
14 GCEL	India
15 GEC Telecommunications Ltd	UK
16 Gfeller AG	Switzerland
17 GTE Telecommunicazioni SpA	Italy
18 Harris	USA
19 Hasler Ltd	Switzerland
20 Indian Telephone Industries Ltd	India
21 Iskra	Yugoslavia
22 Italtel	Italy
23 Japan Radio Co	Japan
24 kabekmetal electro GmbH	Germany
25 Karkar Electronics	USA
26 Kokushai Electric Co Ltd	Japan
27 Krone Aktiengesllschaft	Germany
28 MET	France
29 Motorola Inc	USA
30 Murray Telecommunications Group	Ireland
31 NEC	Japan
32 NKT	Denmark
33 Nokia Telecommunications	Finland
34 Northern Telecom Ltd	Canada
35 PCL	India
36 Philips Kommunikations Industrie	Germany
37 Samsung S & T Co Ltd	R.Korea
38 Siemens AG	Germany
39 SR Ttelecom	Canada
40 Standard Electrica SA	Spain
41 Standard Elektrik Lorenz	Germany
42 Standard Telefon og Kabelfabrik	Norway
43 STC plc	UK
44 Tadiran Ltd	Israel
45 Taihan Electric Wire Co	R. Korea
46 Telesystemes	France
47 Thomson CSF	France
48 Thorn EMI Technology Group	UK
49 Toshiba Corporation	Japan
50 TRT	France
51 Varian AG	Switzerland

Annex 6.2

Common machines & testers for production of about 1000 terminals/ repeaters of Transmission systems of various types

Based on pure assembly & testing basis

MACHINE/TESTER	no. reqd.	Unit Cost US$	Total cost US$
A. INCOMING INSPECTION			
1. RLC Meter	2	7,500	15,000
2. Device testers for			
a) Active discrete devices	2	15,000	30,000
b) Transformers	1	15,000	15,000
c) Relays	1	5,500	5,500
d) Hybrid Micro Circuits	1	1,300	1,300
e) IC's TTL & CMOS	2	600	1,200
f) IC's-Universal	1	60,000	60,000
g) LSI's	1	3,500	3,500
h) Memories	1	1,500	1,500
i) Crystals	1	7,000	7,000
j) Linear IC's	1	20,000	20,000
3. IC handlers	2	7,000	14,000
4. Miscellaneous	2	15,000	30,000
Total A:			204,000
B. Card Assembly-Kitting			
1. Lead Forming Machines			
a) IC Preforming Machines	1	3,000	3,000
b) Axial type comp. crop/ form machines	1	2,000	2,000
c) Radial type comp. Crop/ Form machines	1	2,000	2,000
d) Universal Comp Preparat-ion Machines	1	3,000	3,000
e) Radial super jig for (d)	1	1,000	1,000
2. Comp. Counting M/c's	2	1,000	2,000
3. Tape Dispensers	3	500	1,500
4. PCB Offset Marking M/c's	2	1,000	2,000
5. Others	Lot		3,000
Total B:			19,500

(continued)

Annex 6.2 (continued)

Common machines & testers for production of about 1000 terminals/ repeaters of Transmission systems of various types

Based on pure assembly & testing basis

MACHINE/TESTER	no. reqd.	Unit Cost US$	Total cost US$
C. Component insertion & Wave soldering			
1. Semi Auto Machines	10	20,000	200,000
2. Manual Stations	20	1,500	30,000
3. Conveyor belt systems per 10 stations	3	2,000	6,000
4. Loaded PCB Comparators	3	3,000	9,000
5. Wave Soldering Machines	2	15,000	30,000
6. Aquous cleaners	1	15,000	15,000
7. Main Lead Trimming M/c's	2	7,000	14,000
8. DI Water Plant	2	7,500	15,000
9. Rework Stations	4	1,200	4,800
10. Others	lot		20,000
Total C:			382,800
D. Card Assembly			
1. Automator Lever Press	2	200	400
2. Rivetting Gun	1	250	250
3. Insert Machine	1	200	200
4. Power Screw Drivers	3	200	600
5. Flat Cables/Connector crimps	1	150	150
6. Thermal strippers	2	100	200
7. Pneumatic vices	5	150	750
8. Manual Torque Screw drivers	2	50	100
9. Hot Air Blowers	2	100	200
10. Others	Lot		1,000
Total D:			3,850

(continued)

Common machines & testers for production of about 500 terminals/ repeaters of Transmission systems of various types

Based on pure assembly & testing basis

MACHINE/TESTER	no. reqd.	Unit Cost US$	Total cost US$
E. Rack Assembly kitting			
1. Power cable cutter	1	250	250
2. Pressfit inserting M/c's	1	1,000	1,000
3. Insertion force controller	1	500	500
4. Retention force contoller	1	500	500
5. Connector repairing tool set	1	500	500
6. Sleeve marking machine	1	250	250
7. Wire prefeed system	3	250	750
8. Auto twisted pair cut/ strip machines	1	500	500
9. Crimping tool	1	100	100
10.Crimping jaws	1	100	100
11.Auto feeding crimping M/c's	1	1,000	1,000
12.Hot air blower Gun	2	250	500
13.Others	lot		2,000
Total E:			7,950
F. Final Assembly & Wiring			
1. Power screw drivers of sorts	6	150	900
2. Automator Lever presses	2	200	400
3. Torque control device	1	250	250
4. Rivetting gun	1	250	250
5. Soldering gun	1	250	250
6. Torque screwdrivers of sorts	2	150	300
7. Air controlled wrapping guns	2	100	200
8. Cable set testing machine	1	350	350
9. Wrapping Pull off tester	1	200	200
10.Test Unit for Cords & plugs	1	400	400
11.Rack trolleys	3	400	1,200
12.Others	Lot		2,000
Total F:			6,700

(continued)

Annex 6.2 (continued)

Common machines & testers for production of about 500 terminals/ repeaters of Transmission systems of various types

Based on pure assembly & testing basis

MACHINE/TESTER	no. reqd.	Unit Cost US$	Total cost US$
G: Common testing equipment			
1. Logic Probes & Pulsers	2	725	1,450
2. Oscilloscopes	20	3,000	60,000
3. Multimeters	10	150	1,500
4. Gang Programmer & Eraser	1	7,000	7,000
5. Terminals	10	500	5,000
6. PSU's	10	300	3,000
7. MICE	8	7,000	56,000
8. MDS	1	30,000	30,000
7. IBM PC's	20	1,200	24,000
8. IBM PC/XT's	6	1,500	9,000
9. IBM PC/AT's	4	4,000	16,000
10. 132 column printers	6	800	4,800
11. 80 column printers	24	400	9,600
12. CAD stations & accessories	2	8,000	16,000
13. IBM PC Software	1	5,000	5,000
14. UPS (50 KVA)	1	30,000	30,000
16. Climatic Chambers	5	10,000	50,000
Total G:			328,350

SUMMARY

A: Inward goods inspection	204,000
B: Card kitting	19,500
C: Component insertion & wave soldering	382,800
D: Card Assembly	3,850
E: Rack assembly kitting	7,950
F: Final Assembly	6,700
G: Common test equiment	328,350
Total	953,150

Besides the above equipment, additional investment will be needed for certain special tools and testers specific to the different e.g. for radio systems, Opticsal fibre systems etc.

Chapter 7

Optical Fibre Systems

7.1 Introduction

As discussed in chapter 6, transmission systems are an important component of the PSTN, and among the transmission systems, digital optical fibre systems are today the most cost effective for normal flat terrain. Optical fibre cables and the electronic systems consisting of the optical line terminals and regenerative repeaters together constitute the digital optical transmission systems. A general description of a typical system, an approximate idea of the international cost of a typical system, and an analysis of the inputs required for the production of a typical optical line terminal follow.

7.2 General description of a typical optical fibre transmission system

Fig 7.1 gives a block schematic of a typical 140 Mb/s digital optical fibre system, connecting two stations A and B with a repeater in between. While an 140 Mb/s has been shown, the 2 Mb/s, 8 Mb/s, 34 Mb/s and higher order systems are essentially similar. As can be seen, the system consists of:

- Line terminal equipment, essentially identical, at the two end stations:
- The connecting optical fibre cable
- A repeater. While only one repeater is shown, depending on the length of the route there can be as many as needed. Typically for a 140 Mb/s system the repeater spacing is of the order of 50 Km.

7.2.1 Line Terminal equipment

The line terminal equipment essentially consists of two parts:

a) A Digital multiplex section
b) An optical line terminal

7.2.1.1 Digital multplex section:

In a typical modern digital switching system, the inter node/exchange trunks emerge as a number of 2 Mb/s digital streams consisting of 30 digital channels of 64 Kb/s, each capable of supporting a single voice channel. For transmission over a 140 Mb/s optical fibre transmission system, these are multiplexed into a single 140 Mb/s channel and at the receiving end demultiplexed back into 2 Mb/s channels. This is done in a series of multiplexers and demultiplexers. The fig 7.1 shows three stages of multiplexers/demultiplexers, first one multiplexes 4 channels of 2 Mb/s into a single channel of 8 Mb/s, the second one multiplexes 4 such 8 Mb/s channels into one 34 Mb/s channel and the third and final one multiplexes 4 channels of 34 Mb/s into one of 140 Mb/s. Demultiplexing of one 140 Mb/s channel into 64 channels of 2 Mb/s takes place through the same series of multiplexers/demultiplexers in reverse order. Alternatively, skip multiplex systems are also available in which 16 channels of 2 Mb/s are multiplexed/ demultiplexed in a single stage to and from a 34 Mb/s channel.

Channels of various bit rates pass through a digital distribution frame from one stage of multiplex/demultiplex to another. This provides a point of flexibility and facility to drop and insert channels to different routes in a large station.

7.2.1.2 Optical line terminal

The optical line systems consists of 6 functional modules:

1) **Transmitter Convertor (XMT CONV)**: The basic function of this module is to accept the nominal 140 Mb/s in CMI (Coded Mark Inversion) code, convert it into mBnB e.g. 5B6B code, and add the additional digital channels for, order wire working, for transmitting supervisory information and signals for n + 1 channel switching, collectively known as service data channels. The output from the Transmitter convertor is nominally 168 Mb/s in mBnB code.

2) **Electrical to Optical Convertor (E/O CON)**: The basic function of this module is to convert the 168Mb/s electrical signal into a 168Mb/s optical signal suitable for transmission on an optical fibre. The module basically consists of a suitable light source (a light emitting diode or a laser diode) whose output is suitably modulated by the electrical signal. The 168Mb/s optical signal is then fed to the optical fibre through a fibre distribution frame, which provides a flexibility point to enable connection of an optical line terminal to any fibre terminated on the frame. The connection is made by suitable optical patch cords.

3) **Optical to Electrical Convertor (O/E CONV)**: The basic function of this module is to receive the 168Mb/s optical signal transmitted from the other end on another optical fibre, convert it into 168Mb/s electrical signal and suitably equalise and amplify it. The heart of this module is a photodetector device usually a photodiode.

4) **Receive Convertor (RCV CONV)**: This module receives the 168 Mb/s electrical signal from the Optical to Electrical convertor, seperates out the service data signals, and converts from 168Mb/s mBnB coded signals into the CMI coded 140 Mb/s signal and delivers the same to the demultiplexers.

5) **Service Data Interface (SD INTF)**: This module interfaces between the transmit and receive paths and the service channels viz. order wire phone circuit, supervisory signals and n+1 line switching signals. In the transmit direction it receives the signals from various service channels, and multiplexes and feeds them to transmitter convertor. On the receive side it receives the service data in digital form from the receive convertor, demultiplexes it and delivers it to the different service channels.

6) **Alarm Control and Remote data interface (ACU & RMT INTF)** This module acts as an interface between the transmission and receive paths and display devices for system alarms and service data received from remote stations and repeaters. It receives signals from various devices locally and at remote stations, about their health etc and after suitable processing delivers them to an alarm display panel and to a central supervisory system panel when equipped and to a portable control terminal. It also delivers it to the tranmitter convertor for transmission and display at other stations.

The line terminals are essentially the same at both ends with the different modules performing the same functions in opposite directions.

7.2.2 Optical fibre cable

Optical fibre cable consists of a suitable number of optical fibres in pairs enclosed in a suitable sheath. The fibres are hair thin glass fibres fabricated to extremely close tolerances to a specification which permits light waves to travel in them. The construction of fibres and cables is discussed in greater detail in one of the following chapters. One fibre is needed for transmission in each direction.

7.2.3 Optical repeaters

The light waves suffer attenuation while travelling in the fibre and at joints, bends etc. For error free transmission it is necessary that the signal does not fall below a certain level. A repeater is inserted before that limit is reached. The repeater converts the received attenuated signal to electrical signal, checks it for any errors and regenerates the optical signal for further transmission. The repeater thus essentially consists of two line terminals back to back without the code conversion function. As can be seen the repeater equipment consists of optical to electrical and electrical to optical convertors in either direction. These are essentially identical to the corresponding modules in the terminal equipment. Between the two convertors is the **Branch** module. This module has an error detector and a seperator and a combiner for the service data signals. The Service data and Alarm control and remote data interfaces are identical to those at the terminal equipment.

7.3 Manufacturers of Optical fibre transmission systems

A very large number of companies are producing optical fibre transmission systems. These include almost all the leading manufacturers of comprehensive range of telecommunications equipment and certain others. Table 7.2 lists some of the leading ones largely based on list of exhibitors at Telecom 87 at Geneva.

7.4 International prices

As brought out in chapter 4 in connection with the switching systems, it is extremely difficult to quote a standard international price for the telecommunications equipment. Prices quoted by different suppliers vary widely by an order of 2 to 3 times in the same tender, and by the same supplier in different tenders. Annex 7.3 summarises typical average prices at which orders have been placed for a typical 140 Mb/s equipment on the basis of an international tender.

7.5 Components required for a typical 140 Mb/s optical line terminal

As seen in fig 7.1 giving the block diagram of a typical 140 Mb/s optical transmission system, the system consists of a number of subsystems each of which in turn consists of a number of modules. For purposes of illustration, table 7.4 gives the typical component requirements for a typical optical line terminal consisting of the Transmit, Electrical to Optical, Optical to Electrical, and Receive convertors; the Service Data and Alarm Control and Remote Data Interface Units; and the associated power supply unit modules.

Though consisting of only 8 modules, the equipment calls for a large number and variety of components.

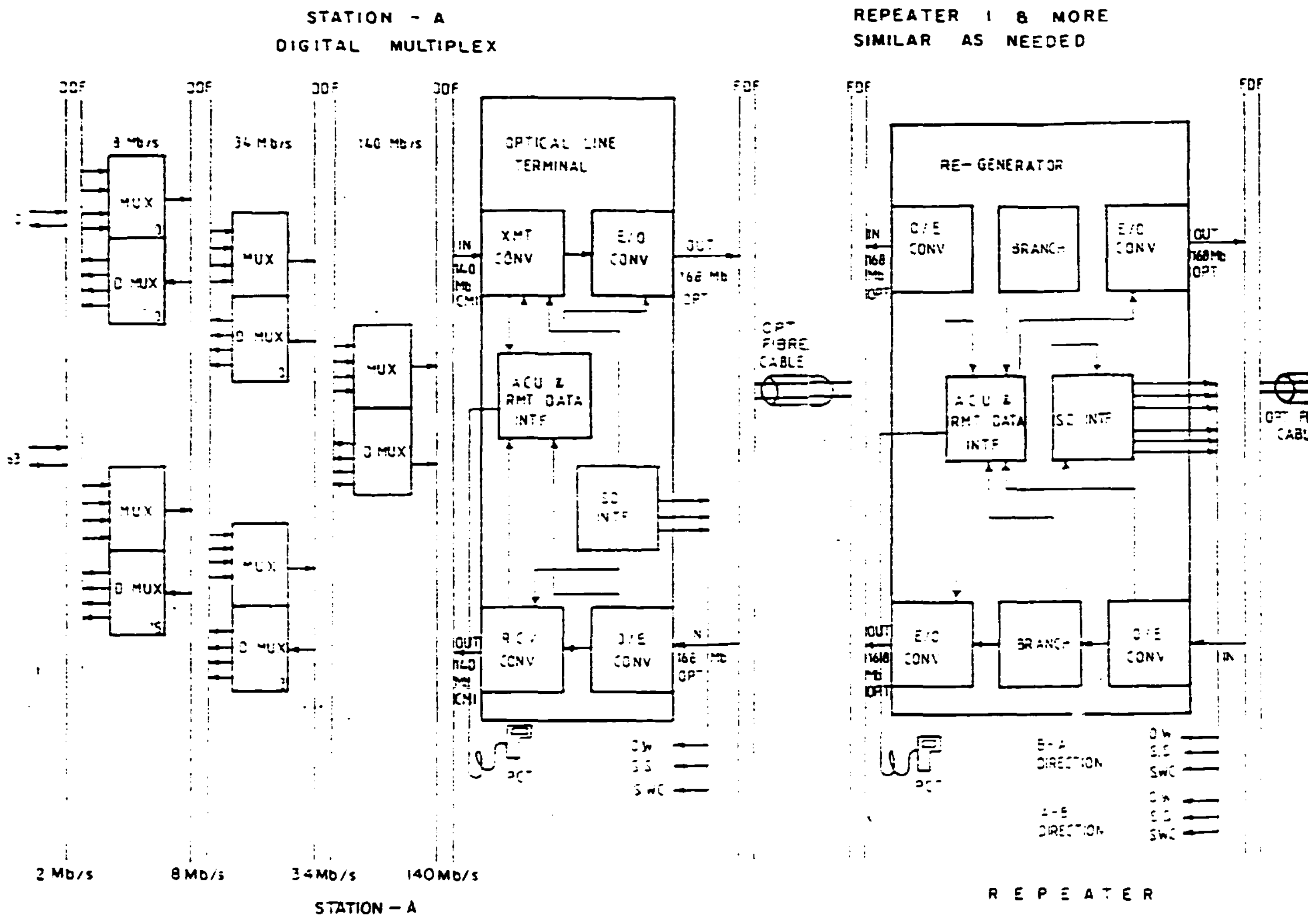
Annexed:

Annex 7.1: **Fig 7.1 giving a block diagram of a typical 140 Mb/s optical fibre transmission system**

Annex 7.2: **A partial list of leading manufacturers of optical fibre transmission equipment**

Annex 7.3: **Typical prices for a 140 Mb/s Optical fibre transmission system**

Annex 7.4: **Component requirements for a typical optical line terminal forming part of the optical fibre transmission system**

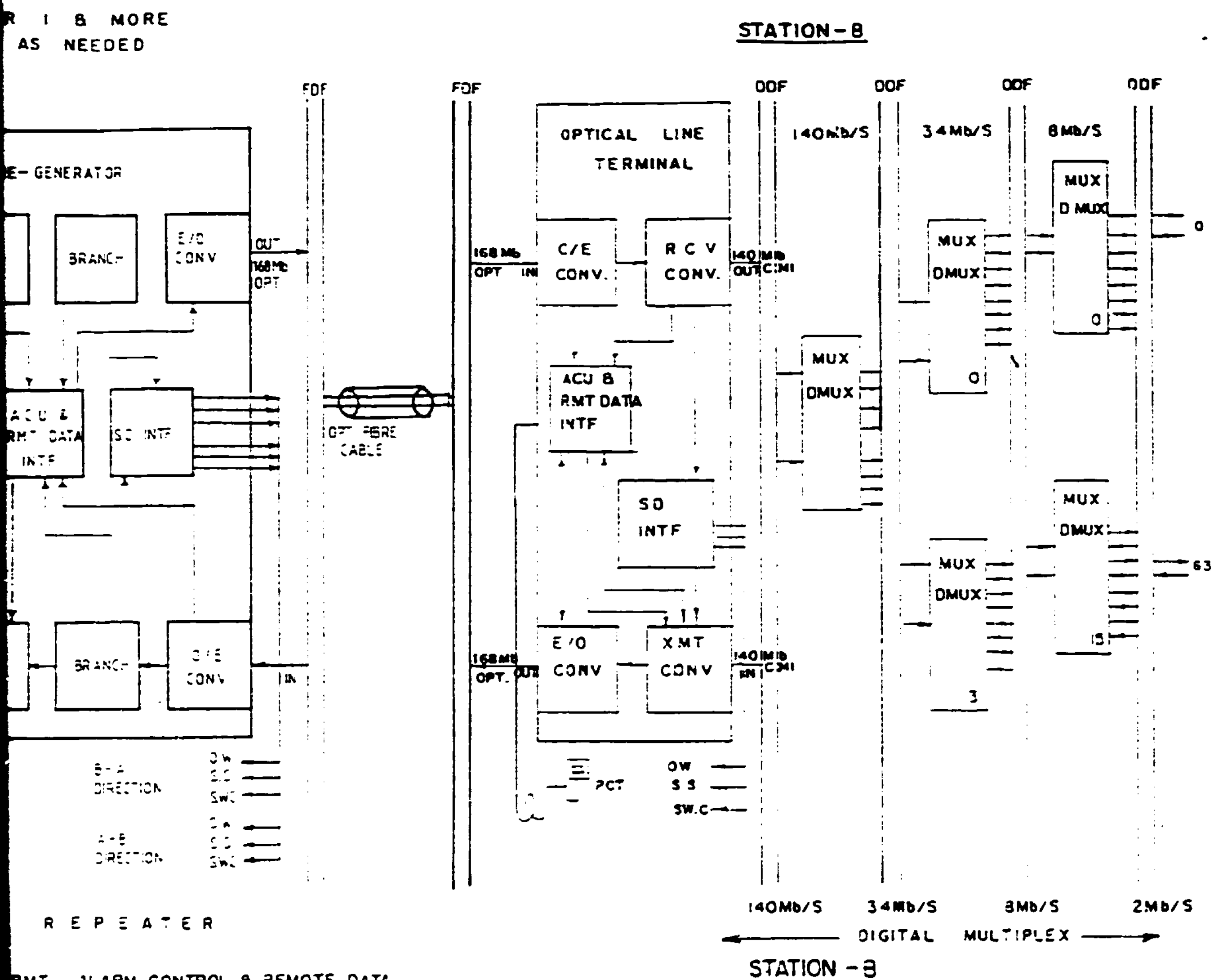


LEGEND

- DDF — DIGITAL DISTRIBUTION FRAME
- FDF — FIBRE DISTRIBUTION FRAME
- XMT CONV — TRANSMITTER CODE CONVERTER UNIT
- RCV CONV — RECEIVER CODE CONVERTER UNIT
- E/O — ELECTRICAL TO OPTICAL CONVERTER UNIT
- O/E — OPTICAL TO ELECTRICAL CONVERTER UNIT
- ACU &RMT DATA INTF — ALARM CONTROL & REMOTE DA INTERFACE UNIT
- SD INTF — SERVICE DATA INTERFACE.
- OW — ORDER WIRE
- SS — SUPERVISORY SIGNAL
- SWC — SWITCHING CONTROL SIGNAL
- PCT — PORTABLE CONTROL TERMINA

FIG. 7.1 SIMLIFIED BLOCK DIAGRAM OF A TYPICAL 14(

SECTION 1



RMT ALARM CONTROL & REMOTE DATA
NTF INTERFACE UNIT
F SERVICE DATA INTERFACE
ORDER WIRE
SUPERVISORY SIGNAL
SWITCHING CONTROL SIGNAL
PORTABLE CONTROL TERMINAL

RAM OF A TYPICAL 140 Mb/S O.F. SYSTEM

Table 7.2

A partial illustrative list of manufacturers of optical fibre equipment

Name of Manufacturer	Country
1 ABC Teleinformatica S/A	Brazil
2 AT&T	USA
3 AT&T & Philips	Netherlands
4 Alcatel CIT	France
5 BTM	Belgium
6 Ericsson	Sweden
7 Fujitsu	Japan
8 GEC Telecommunications Ltd	UK
9 GTE Telecommunicazioni SpA	Italy
10 Gfeller AG	Switzerland
11 Hasler Ltd	Switzerland
12 Indian Telephone Industries Ltd	India
13 Iskra	Yugoslavia
14 Italtel	Italy
15 kabekmetal electro GmbH	Germany
16 Krone Aktiengesllschaft	Germany
17 Murray Telecommunications Group	Ireland
18 NEC	Japan
19 NKT	Denmark
20 Nokia Telecommunications	Finland
21 Northern Telecom Ltd	Canada
22 Optel	India
23 Philips Kommunikations Industrie	Germany
24 STC plc	UK
25 Siemens AG	Germany
26 Standard Electrica SA	Spain
27 Standard Elektrik Lorenz	Germany
28 Standard Telefon og Kabelfabrik	Norway
29 Tadiran Ltd	Israel
30 Taihan Electric Wire Co	R. Korea
31 Telesystemes	France
32 Thomson CSF	France

Table 7.3

Typical international price of a typical 180 Km 140 Mb/s Optical fibre System (Equipment & cables)

Sl no.	Item	Unit Price US$	Qty Reqd. (No.)	Total Cost US$	Total Cost %
1.	OPT LINE TERM 140 MB/s	3,250	2	6,500	1.00
2.	Order Wire equipment one for each terminal & repeater station	1,500	5	7,500	1.16
3.	Repeater regenerator equipment	2,800	3	8,400	1.29
4.	Digital Multiplex equipment				
4.1	4th order (140 Mb/s) Mux	2,200	2	4,400	0.68
4.2	3rd and 2nd order (4 of 34 Mb/s and 16 of 8 Mb/s at each end)	13,000	2	26,000	4.01
5.	Fibre Distribution Frame	500	5	2,500	0.39
6.	Digital Distribution frame	3,000	2	6,000	0.92
7.	Installation material				
	Terminal stations	3,000	2	6,000	0.92
	Repeater stations	2,000	3	6,000	0.92
	Sub-total transmission equipment			73,300	11.29
8.	Fibre optic cable, 12 fibre, jelly filled,metalless	2,900	180	522,000	80.44
9.	Splicing material				
9.1	Closures	150	200	30,000	4.62
9.2	Splice trays	50	400	20,000	3.08
10.	Termination sets				
10.1	Wall mountable splice centre	98	5	500	0.08
10.2	rack mounting kit	32	5	160	0.02
10.3	splice trays	50	20	1,000	0.15
10.4	Fan out cord with D4 connector	50	40	2,000	0.31
	Sub-Total Fibre-optic cable & accessories			575,660	88.71
	Total Cable & Equipment			648,960	100.00
	Per channel material investment cost for a fully equipped system			US$ 338	

Notes:

The above table does not include cost of infrastructure like building, environmental control, and main power supply equipment, as well as cost of laying of cable & installation of equipment.

In addition to equipment and cables, for installation and maintenance, following tools & testers will also be needed. These can however be used in common for a number of systems in the same network.

Item		Unit Cost US$		Total Cost US$
1.	Special tools for equipment Installation	2,225	1 set	2,225
2.	Splicing machine & accessories	40,000	1 set	40,000
3.	Test Instruments	80,000	1 set	80,000
	Total			122,225

Table 7.4

Component requirements for a typical 140 Mb/s Optical fibre System Terminal

Component	Types used (no.)	Qty. Rqd. (no.)
1 Avlanche Photodiode Modules	1	5
2 Capacitors fixed	v	506
3 Capacitors variable	v	6
4 Coils	6	32
5 Connectors		
6 Delay lines	3	3
7 Diodes	38	143
8 Dip Switches	-	3
9 Hybrid Circuits	4	6
10 Integrated circuits	96	147
11 Laser Diode Modules	1	5
12 Oscillators Voltage controlled	2	2
13 PCB's	7	10
14 Photo couplers	3	3
15 Relays	2	2
16 Resistors fixed	v	685
17 Resistors network	v	20
18 Resistors variable	4	30
19 Switches	2	2
20 Transformers	v	7
21 Transistors	26	82

In addition to above, iron work and connectors and cables of various types will also be required.

V = various

Chapter 8

A typical digital radio transmission system
8Mb/s 120 channel PSK (Phase shift keying) Radio System

8.1 Introduction

In chapter 6, various telecommunication transmission systems have been briefly discussed. Digital systems have become highly cost effective and provide high quality transmission. They are available for application on various media like symmetrical & coaxial cables, optical fibre cables and radic. For radio application, both terrestrial and satellite, a whole range of systems from a few channels, as few as 10, to as many as 1920 are available in different frequency bands. In this chapter a simple description is attempted of a typical 8 MB/s radio system for 120 channels using PSK (Phase shift Keying) modulation in 600 Mhz (UHF) band, followed by a brief idea of international prices and an analysis of the main components required for the manufacture of the system.

6.2 Simplified Functional description

Fig 8.1 is a simplified block schematic of an 8Mb/s PSK radio system. Together with the appropriate digital multiplex system, it provides 120 two way voice/data grade 64 Kb/s channels. On the transmission side, the system accepts nominal 8Mb/s 120 channel PCM stream from a digital multiplexer, adds to it additional bits for order wire supervision, BER measurement etc. PSK modulates it with a 600 MHz carrier frequency, amplifies the signal and delivers it to the antenna through a channel duplexing module. On the receive side, it receives the PSK modulated radio signal from the antenna through the channel duplex module, amplifies it, and demodulates it to give two parallel 4.352 Mb/s streams. It then combines the two parallel streams into a single 8Mb/s signal, extracts out from it the order wire and supervisory bits, changes the speed to 8.448 Mb/s and delivers the signal to the demultiplex equipment.

Both the transmit and receive paths are fully duplicated and are available in hot standby for change over in case of any failure or serious deterioration of performance of the working channel.

As can be seen from the fig 8.1 the system consists of following functional blocks:

1) **Trans Hybrid & Receice Switching (TR HYB) Unit**
2) **Bipolar/Unipolar Conversion (B/U Conv) Unit**
3) **Multiplex (MUX) Unit**
4) **Up Convertor (Up Conv) or Transmitter Unit**
5) **Channel Duplexer (DX CH) unit**
6) **Down Convertor (DN CONV) or Receiver Unit**
7) **Synchronistion (SYNC) Unit**
8) **Demultiplex (Demux) Unit**
9) **Digital Order Wire & Supervisory Interface (SV INTF) Unit**
10) **Control (CON) Unit**

Each of these units in turn consists of one or more modules mounted on suitable Printed circuit boards.

8.2.1 Trans hybrid & Receive switching unit(TR HYB):

This is a unit common to the two transmitters and receivers, main and standby.

On the transmit side, this unit receives the nominal 8Mb/s (actual 8.448 Mb/s) digital signal from second order digital multiplexer and and using a hybrid transformer divides the signals in two halves to feed the two parallel transmit paths, main and standby.

On the receive side it connects one of the two receive paths, main or standby, through a mercury switch to the digital demultiplexer, under control of a control signal from Control CPU.

8.2.2 Bipolar/Unipolar Convertor Unit (B/U CONV):

This is a duplicated unit, one for main and the other for standby system, but serving both the trans and receive paths.

On the trans side, it converts the 8.448 Mb/s bipolar signal to a unipolar and a clock signal and delivers the two to the Multiplex unit.

On the receive side it converts the unipolar signal received by it from demultiplex unit into a bipolar signal and delivers it to the TR HYB unit for finally passing it on to the digital multiplex system.

8.2.3 Multiplex (MUX) unit:

MUX unit is exclusive to the trans path, one for each transmitter. It receives the 8.448 Mb/s unipolar signal from B/U CONV and performs the following functions on the signal before delivering it to the UP Conv Unit:

- At SPD Convertor module, converts the signal speed from 8.448 Mb/s to 8.704 Mb/s to enable insertion of additional bits.
- At BITS INS module, inserts additional bits for order wire, supervision, parity check etc into the data stream.
- At Serial to Parallel (S/P Con) Convertor module, rearranges the 8.704 Mb/s single stream into two parallel 4.352 Mb/s streams for PSK modulation.

8.2.4 UP CONV UNIT:

This again is a unit exclusive to each transmit path and performs the following functions on the two parallel 4.352 Mb/s signals received from the MUX unit before delivering a radio frequency signal to the Channel Duplexer unit for feeding to antenna:

- At the T logic module performs the logics for differential modulation and signal waveform shaping.

- At the Modulator module. an RF linear 4 PSK modulator. modulates the signal with a 600 Mhz RF carrier.

- The 600 MHz carrier is generated using a synthesizer oscillator and buffer multiplier module.

- At the Power Amplifier (PA) module. the modulated RF signal is amplified by a linear amplifier. The output is typically 2 watts. The signal is now passed on to the Channel duplexer unit.

8.2.5 Channel Duplexer unit:

This is a unit common to both the main and the standby transmitters and receivers.

In the transmit path it receives the modulated and amplified signals from the two transmit channels. main and standby. and at the diode switch switches one of them to the antenna through a band pass filter. under the the control of trans control signal received from the CPU control module of the Control unit. The output of the antenna is typically 1 watt plus.

In the receive path. the unit receives from the antenna. the Radio frequency signal received from the other end. The signal is seperated from trans signal by a band pass filter and is fed to the two receive channels via a RF Hybrid.

8.2.6 Down Convertor:

This is a unit exclusive to each receive path and performs the following functions on the received radio frequency signal to deliver two parallel 4.704 Mb/s streams to the Synchronisation unit:

- At the RF module. the received signal is amplified by a low noise amplifier. and mixed in an image cancel type mixer with a signal generated using a synthesizer oscillator. to give an intermediate frequency (IF) signal in 70 MHz band. The signal passes through a band pass filter and is amplified by an automatic gain cotrol (AGC) amplifier. The amplified IF signal then passes on to the demodulator module.

- At the demodulator module, the signal is demodulated by synchronous detection and then fed to the Rx logic module.

- At the Rx Logic module. two parallel 4.352 Mb/s signals are regenerated and passed on to the synchronisation unit

8.2.7 Synchronisation unit

This is also a unit exclusive to each receive path. The unit receives the signal from the down convertor unit and performs the following functions before delivering it to the Demultiplex unit:

- At the P/S Conv module arranges the two 4.352 Mb/s parallel streams into a single, series 8.704 Mb/s stream

- At the Synch module recovers the frame synchronizing pattern which is used in Descram module for descrambling the data stream and generating timing pulses for seperation of auxialary bits in the demultiplex unit.

8.2.8 Demultiplex unit

This unit is also exclusive to each receive path. It receives the 8.704 Mb/s signal and timing information from synchronous unit and performs the following functions before delivering a 8.448 Mb/s unipolar and a clock signal to the B/U unit.

- Extract the auxialary bits. Order wire, supervisory, parity check etc. from the 8.704 Mb/s signal

- Convert the speed to 8.448 Mb/s

  The 8.448 Mb/s unipolar and clock signals are passed on to the **B/U unit**, which, as already noted, is a common unit to the trans and receive paths. In the B/U unit the Unipolar 8.448 Mb/s signal is converted back to bipolar signal and fed to the TR HYB Unit

- The parity check bit is used to monitor the bit error rate.
- The digital order wire and supervisory signals are passed on to the Control unit.

As already noted the **TR HYB unit** is common to the trans and receive paths. The 8.448 Mb/s regenerated signal from both the receive channels is fed to this unit and at a mercury switch, one of them is selected and passed on to the digital multiplex system, under the control of a control signal from the the supervisory unit.

8.2.9 Orderwire and supervisory interface

The order wire telephone speech is converted in the PCM Codec module to 64Kb/s stream and fed to the MUX unit in the trans via the control unit path for insertion in the trans channel. The 64 Kb/s voice signal from distant end is received from the demultiplex unit and converted to analog speech and fed to the order wire telephone circuit.

The supervisory information consisting of various parameters (upto 12) about the various equipments is collected and converted into a 64 Kb/s digital channel and fed to the MUX unit in trans path for transmission to remote station. The 64 Kb/s supervisory information channel received from remote station is seperated at the DEMUX unit and processed and displayed at the the display panel. It is also fed to the control CPU for control of switching of the trans and receive paths from main to standby and vice versa.

8.2.10 Control unit

The unit provides an order wire telephone circuit, a change over control circuit, an indicator and alarm circuit and a monitoring meter circuit and works in conjunction with the Digital orderwire & Supervisory interface unit.

8.3 Application as a repeater

The above system with a terminal at each end, and antenna mounted at an optimum height can provide direct communication between two stations about 50 to 60 Km apart in a flat terrain. For communication between stations situated further apart this can be done using repeaters each consisting of two terminal equipments connected back to back. Since the signals are regenerated at each repeater, a fairly large number of such repeaters could be used without any significant deterioration in quality of communication from end to end.

To provide centralized control and maintenace, of both the terminals and the repeaters, a centralised supervisory system is incorporated with a master unit at the designated central station and slave units at the repeaters and the distant station. Typically one master unit can control about 16 slave units. The supervisory information is processed by the supervisory interface module of the Digital orderwire & supervisory interface unit for transmission and reception over the radio system via the MUX and DEMUX units in the trans and receive paths.

8.4 Manufacturers

Many of the companies listed in table 6.1 in chapter 6 are manufacturing and supplying the equipment.

8.5 Pricing

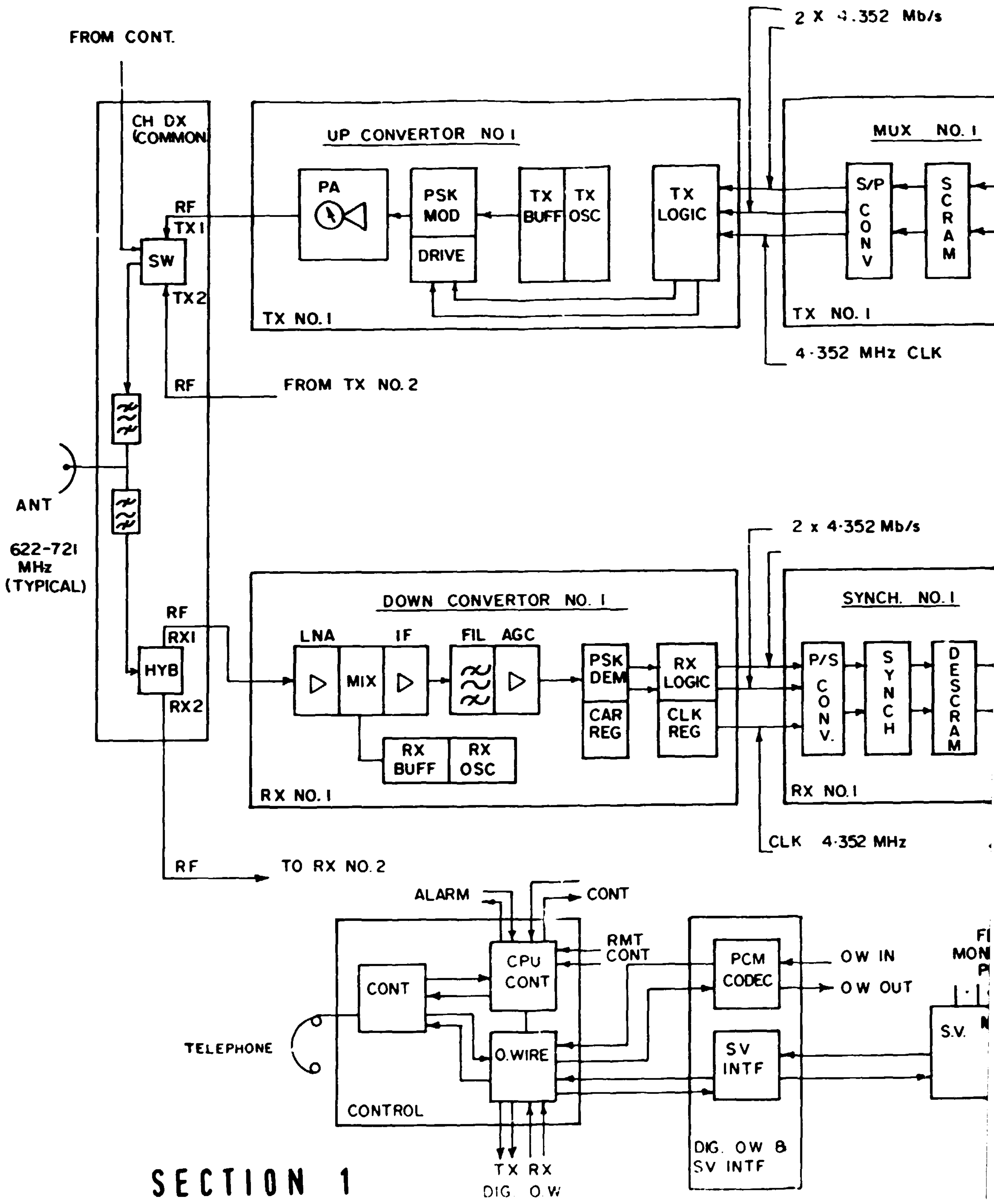
The difficulties in quoting any specific figure for international pricing brought out in connection with switching equipment prices apply equally in this case. However to give a general idea typical prices at which some orders have been placed against certain international bids are indicated in Table 8.2 for a typical 200 Km route with three repeaters.

8.6 Components required for production of equipment as an assembly operation

To give a general idea about the the complexity of the system and essential inputs required for its manufacture an analysis has been made of different types of components going into the different units for a single terminal with one transmitter and one receiver . A summary is given in table 8.3

Annexed:

Fig 8.1:	A simplified block diagram for a typical 8 Mb/s (120 channel) radio system terminal.
Table 8.2:	Typical prices for an 8 Mb/s radio relay system in 600 MHz band with duplicated transmitters and receivers as main and standby for a typical 200 km. route with 3 repeaters.
Table 8.3:	List of components required for different units of a typical terminal of 8 Mb/s radio system.


FROM CONT.
CH DX (COMMON)
RF
TX1
SW
TX2
RF
FROM TX NO. 2
ANT
622-721 MHz (TYPICAL)
UP CONVERTOR NO 1
PA
PSK MOD
DRIVE
TX BUFF
TX OSC
TX LOGIC
TX NO. 1
2 X 4.352 Mb/s
MUX NO. 1
S/P CONV
SCRAM
TX NO. 1
4·352 MHz CLK
2 x 4·352 Mb/s
DOWN CONVERTOR NO. 1
RF
RX1
HYB
RX2
LNA
MIX
IF
FIL
AGC
RX BUFF
RX OSC
PSK DEM
CAR REG
RX LOGIC
CLK REG
RX NO. 1
SYNCH. NO. 1
P/S CONV.
SYNCH
DESCRAM
RX NO. 1
CLK 4·352 MHz
RF
TO RX NO. 2
ALARM
CONT
RMT CONT
CPU CONT
CONT
TELEPHONE
O. WIRE
CONTROL
TX RX
DIG. O.W
PCM CODEC
OW IN
OW OUT
SV INTF
DIG. OW & SV INTF
S.V.

SECTION 1

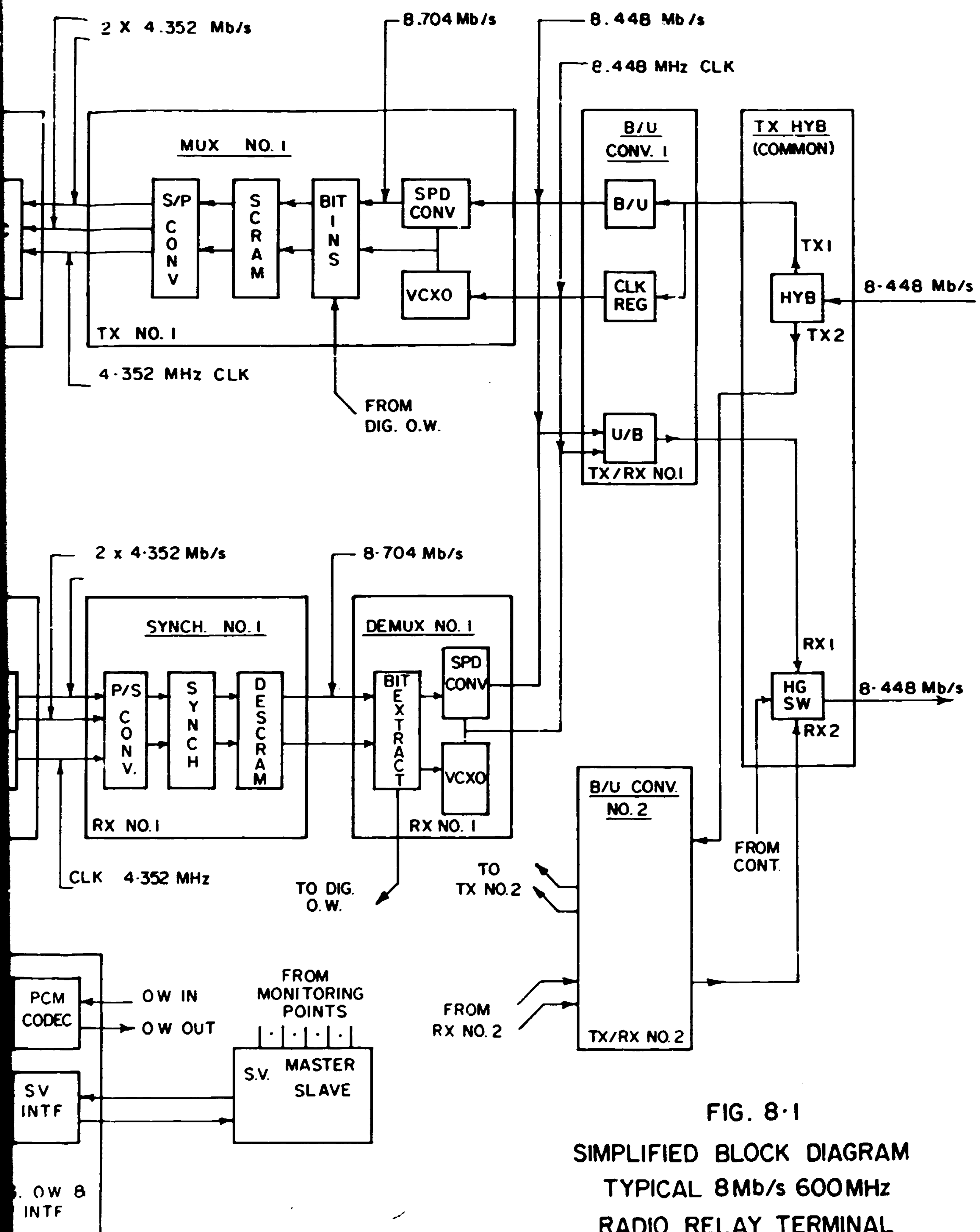


FIG. 8·1

SIMPLIFIED BLOCK DIAGRAM
TYPICAL 8Mb/s 600MHz
RADIO RELAY TERMINAL
DUPLICATED (MAIN + STANDBY) SYSTEM

Table 8.2

Typical prices for an 8 Mb/s radio relay system in 600 Mhz band with duplicated tranmitters and receivers as main and standby for a typical 200 Km route with 3 repeaters

	Item	Qty. Reqd. (No.)	Unit Price US$	Total Price US$
1.	Radio relay terminals one each at two terminal stations and two each at 3 repeaters	8	10,311	82,489
2.	Supy Master unit	1	1,345	1,345
3.	Supy slave units	4	899	3,595
4.	Bit insertion & SV intf	8	1,082	8,652
5.	Branching cir. for O.W.	3	227	680
6.	Installation materials	8	263	2,105
7.	Tools & accessories	5	73	365
8.	3 M Antennas	8	2,185	17,480
9.	Feeder Cable sets	8	1,498	11,985
	Total			128,696
	Per channel			1,072

Table 8.3

Component requirements of a single typical 8 MBps UHF Terminal

Sl No	Item	Qty Reqd (No.)
1	Capacitors, fixed	762
2	Capacitors, variable	3
3	Coils	57
4	Connectors	114
5	Couplers	1
6	Crystals	12
7	Diodes	210
8	Filters	5
9	Fuse holders	3
10	Fuses	3
11	Heat Sinks	4
12	HIF's	8
13	Hybrid Circuits	11
14	I.C. Sockets	3
15	Integrated Circuits (IC's)	279
16	Jacks	23
17	LED's	33
18	Locks	4
19	Mixers	7
20	PCB's	46
21	Photocouplers	13
22	PWR Units	3
23	Relays	30
24	Resistors, fixed	1076
25	Resistors Variable	37
26	Short Plugs	193
27	Speakers	1
28	Switches	28
29	Terminals	309
30	Test Jacks	1
31	Transformers	5
32	Transformers, pulse	6
33	Transistors	83
34	U-Links	14

Note: The above requirements are for an unduplicated system i.e. for a single transmitter and receiver with the necessary common units.

Chapter 9

Optical fibre and cables

9.1 Introduction

It was noted in chapter 6 that digital transmission on optical fibre cables offers the most cost effective means of providing inter node trunks. Chapter 7 covered a typical transmission equipment for fibre optic application. In this chapter it is proposed to cover the basic construction and inputs required for the production of fibre optic cables.

9.2 Construction and production processes for optical fibres for telecommunications application

9.2.1 Optical fibre for telecommunications applications consists of extremely thin solid fibres of silica/glass with a central core of about 50 micro meter diameter for multimode and of about. 8 micro meter for single mode fibres, and an outer cladding of an overall diameter of 125 micro meter . The fibres are provided with a suitable protective coating to avoid ingress of any impurities including moisture and provide mechanical strength. Both the core and cladding are glass but core has a higher refractive index. The relative refractive indices are such that most of the rays of light travelling in the core that may escape into the cladding layer suffer total refelection and are returned to the core, thus minimising the loss of light energy.

9.2.2 The reliability and repeatability of performance of fibres calls for ensuring accuracy in diameters and circularity and concentricty of the core, the cladding and the primary protective coat. The tolerances generally specufied for the fibre are :

• Core diam:	Plus/Minus 6%
• Cladding diam:	Plus/Minus 2.4%
• Core non-circularity:	6%
• Cladding non-circularity:	2%
• Concentricity Error:	6%

9.2.3 Production of glass fibres involves highly sophisticated processes. In the first instance, a preform consisting of a solid cylinder with a central core and the outer cladding, of appropriate quality of glasses is fabricated by one of the several alternative processes. The preform is then drawn into thin fibres which are immediately provided with a primary protective coating. A number of leading companies have contributed to the development of the production technology, among them, STL Laboratories in UK, Nippon Sheet Glass Co.,Nippon Electric Company, and Nippon Telegraph and Telephone Corporation in Japan, Corning Glass Works and Bell Telephone Laboratories in USA, and Philips Industries in Holland.

9.2.4 Bulk of the optical fibres, at present being produced use one of the four vapour deposition processes viz.:

- Modified Chemical Vapour Deposition (MCVD) Process
- Outside Vapour Phase Oxidation (OVPO) Process
- Vapour Axial Deposition (VAD) Process
- Plasma Chemical Vapour Phase Deposition (PVCD) Process

9.2.5 Fig. 9.1 gives a schematic diagram of the **Modified Chemical Vapour deposition (MCVD)** process which involves:

- Heating of a rotating quartz tube from the outside by a number of gas burners moving along the length of the tube.
- Feeding of a number of gasses (Silicon Chloride, $GeCl_4$, $POCl_3$ and Argon) through the quartz tube.
- Oxidation of the gasses by high temperatures and deposition of glass soot on the inner surface of the tube.
- Deposition of 60 to 70 layers of glass soot by repeated passing of the burners.
- Finally collapsing of the tube under high temperature (of the order of 2000 degress centigrade) to form a solid cylindrical preform.

Thus, the core glass is deposited from the gasses by vapour deposition process while the tube acts as the cladding.

9.2.6 Fig 9.2 gives a schematic of the **Outside Vapour Phase Oxidation (OVPO)** process, which involves:

- A rotating seed rod
- Feeding of raw materials through a set of burners.
- Collection by the rotating seed rod, of glass soot, formed by the flame hydrolysis process, at every pass of the burners.
- Forming layer by layer first the core and then the cladding.
- Removal of the hollow cylindrical preform from the seed rod and its consolidation and formation of the solid preform under dry high temperature conditions.

9.2.7 Fig 9.3 gives a schematic of the **Vapour Axial Deposition Process** which involves:

- A rotating seed rod which is gradually pulled up.
- Feeding through two sets of burners the core and cladding materials.
- Deposit below the rotating seed rod first of the core and later the cladding.
- Drying, consolidation and elongation of the preform.
- Overcladding by the rod-in-tube process.

The process permits larger size preforms.

9.2.8 Fig. 9.4 gives the schematic of the **Plasma Chemical Vapour Deposition process**, which is a variation of the Inside Vapour Phase deposition process. The process substitutes the gas burners for heating the gases and formation of glass deposit inside the tube, by a plasma furnace. The furnace resonator creates microwave plasma in the tube with frequencies around 2.5 GHz. The process permits deposition of a large number, of the order of 1000, of very thin layers resulting in an extremely smooth refractive index profile from centre outwards.

9.2.9 Fibre drawing

The preform made through one of the vapour deposition processes as above is used to draw the fibre of the required diameter on a fibre draw tower. Fig. 9.5 gives a schematic of the draw tower. The process involves:

- Feeding of the preform into an induction furnace.
- Melting of the preform at its bottommost end under high temperatures developed in the furnace.
- Molten portion dropping down by gravity and being drawn into the thin fibre by a pulling force applied by the pulling drum.
- Close control of the process to ensure uniformity of diameter. The diameter is closely and continuously monitored by a laser based mechanism. The information collected is used to control the preform feed mechanism, the temperature of the furnace and the speed of the pulling drum.
- Maintenance of ultra pure environment and application of primary protective coating immediately to avoid ingress of impurities. Primary coating consists either of acrylates or silicone and is cured either by ultraviolet curing or thermal drying.

9.2.10 There is considerable competition in the fibre market. Typically, high quality fibre is at present quoted at about US 10 Cents per meter. The quantity and therefore the cost of raw materials going into the production of fibres is quite small. However, the processes for production of preform and for drawing of fibres, call for a high level of sophistication and auotmation by way of close control of chemical inputs, temperatures, speeds etc. to obtain the fibre of acceptable quality. The cost of process machines, Vapour Deposition Lathes and Draw Towers, is thus very high. Use of chemicals also requires significant control measures for environmental protection. The fabrication of optical fibre therefore is cost effective only at substantial production levels, usually over a hundred thousand fibre kilometers per annum. Tables 9.6 and 9.7 give typical figures for the inputs required for fibre fabrication by way of chemicals etc and the plant and machinery.

9.3 Optical fibre cables - Construction & production processes

9.3.1 Primary coated fibres, by themselves lack body and strength for practical application. To provide the necessary body and strength, the required number of fibres from one to 100 or more are put together in cable form. According to the application and requirements of strength, level of protection etc, cabling may involve provision of a secondary jacket, one or more strength members, water protection by way of jelly filling or provision for gas pressurization, sheathing, fillers, cushion materials, armouring etc.

9.3.2 **Fibre Jacketing**: As a first step the individual primary coated fibres are provided a secondary jacket usually of nylon, for further mechanical protection and strength. Two types of jackets, loose or tight, are used. Both have comparative advantages and disadvantages, and adherents. An extruding machine is used for the purpose.

9.3.3 **Strength Members**: To increase the strength, particularly the tensile strength of the cables to permit long lengths being pulled within ducts etc, strength members are added either at the centre of the cable or stranded along the periphery. The strength members may be in the form of steel wires or for metal free construction in the form of plastic monofilaments or special fibres like kelvar.

9.3.4 **Water protection**: Protection against moisture takes the form of either the jelly filling of the stranded cable core, enclosed in a suitable waterproof tape lapping or gas pressuriztion through addition of suitable perforated pipes.

9.3.5 **Sheathing**: Sheathing, usually of plastic material, provides a covering for the cable and holds its elements, fibres, strength members and water protection. An overall external sheath is essentially provided. In addition there might be an inner sheath as well, particularly when cables are armoured for direct burial in ground.

9.3.6 **Armouring**: Armouring in the form of steel tapes or wires or corrugated steel tubes provides extra protection for direct burial of cables in ground. It also provides the only fully reliable protection against rodents. It is generally not provided when cables are to be laid in ducts.

9.3.7 **Fillers**: Fillers are provided in the cable structure when necessary to achieve an overall round cross section.

9.3.8 **Overall structure**: Many variations have been devised in the overall structure of optical fibre cables and there are many adherents of each. Figures 9.8 to 9.10 illustrate three most frequently used structures, Layer, Tight jacket in V-Groove and Ribbon, first two being generally used for small fibre count cables and the third for larger ones.

9.4 <u>Typical international prices of optical fibre cables</u>

There is quite a keen competition in the optical fibre cables market. Depending on the overall structure desired the prices for metalless cables of an average of 10 fibres vary between 3 to 4 US $ per meter.

9.5 <u>Production of optical fibre cables from procured fibres</u>

9.4.1 Chart 9.11 gives a typical process flow and the machines and materials required for production of small count, metalless cable of tight jacket in V-groove structure shown in fig. 9.9 without the armouring. Typical figures for raw material and plant and machinery requirements for an annual production of 2,500 sheath Km of optical fibre cable and international prices thereof are indicated in tables 9.12 and 9.13.

Annexed:

Figure 9.1	Schematic drawing illustrating the Modified Chemical Vapour Deposition process.
Figure 9.2	Schematic drawing illustrating the Outside Vapour phase oxidation process
Figure 9.3	Schematic drawing illustrating the Vapour axial deposition process
Figure 9.4	Schematic drawing illustrating the Plasma Chemical Vapour deposition process
Figure 9.5	Schematic drawing illustrating the working of a fibre draw tower
Table 9.6	Raw material Inputs required for production of preform by MCVD process and drawing the fibres.
Table 9.7	Plant and machinery required for production of preform by MCVD process and for fibre drawing
Figure 9.8	Cross section of an optical fibre cable with 'layer structure'
Figure 9.9	Cross section of an optical fibre cable with 'Tight Jacket in V-Groove structure"
Figure 9.10	Cross section of an optical fibre cable with 'Ribbon structure'
Chart 9.11	Process flow chart for production of cables from bought out fibres
Table 9.12	Raw material inputs for production of optical fibre cables from bought out fibres
Table 9.13	Plant and machinery required for production of optical fibre cables from bought out fibres

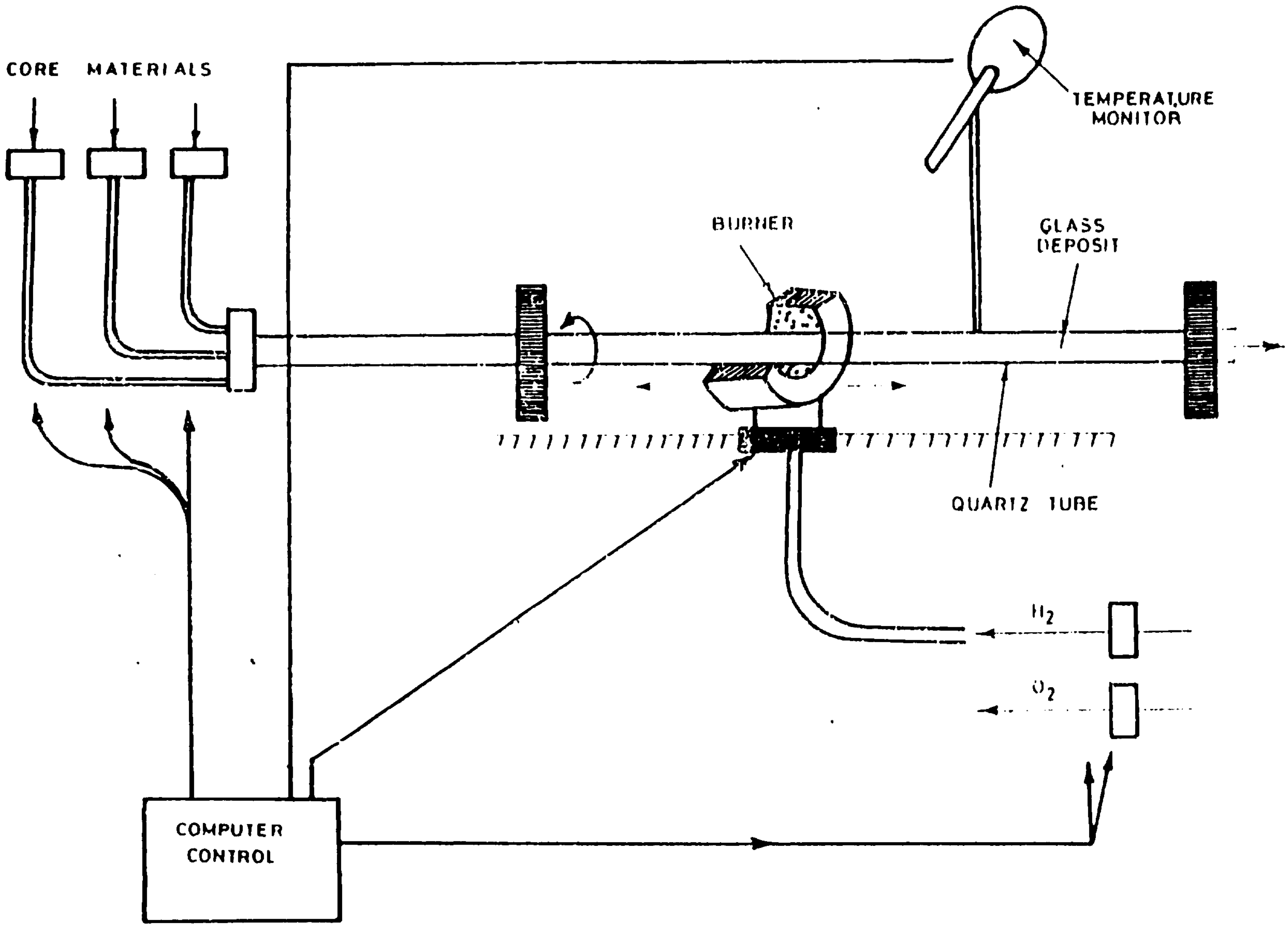


FIG 9·1 Modified chemical vapour deposition process

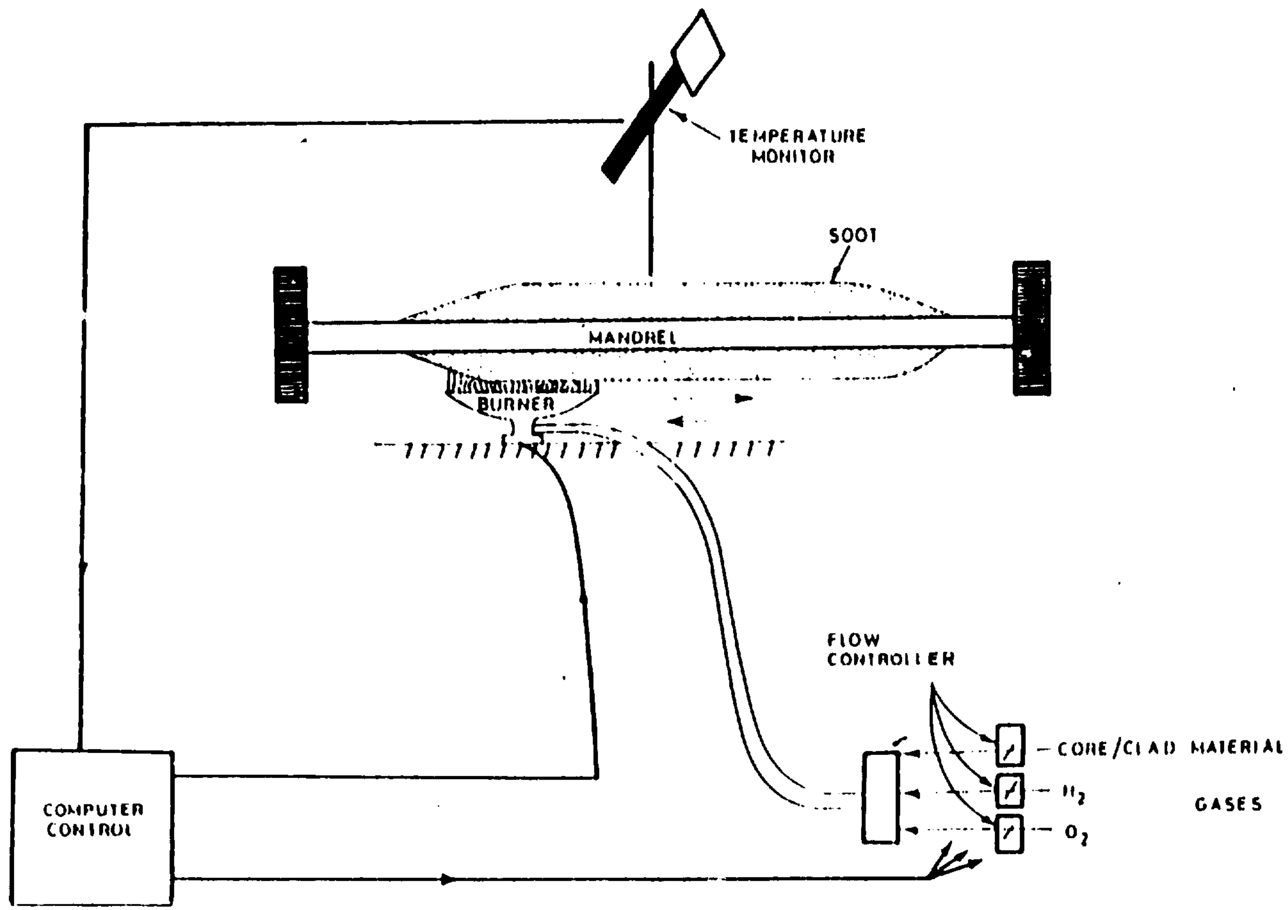


FIG 9·2 Outside vapour phase oxidation process

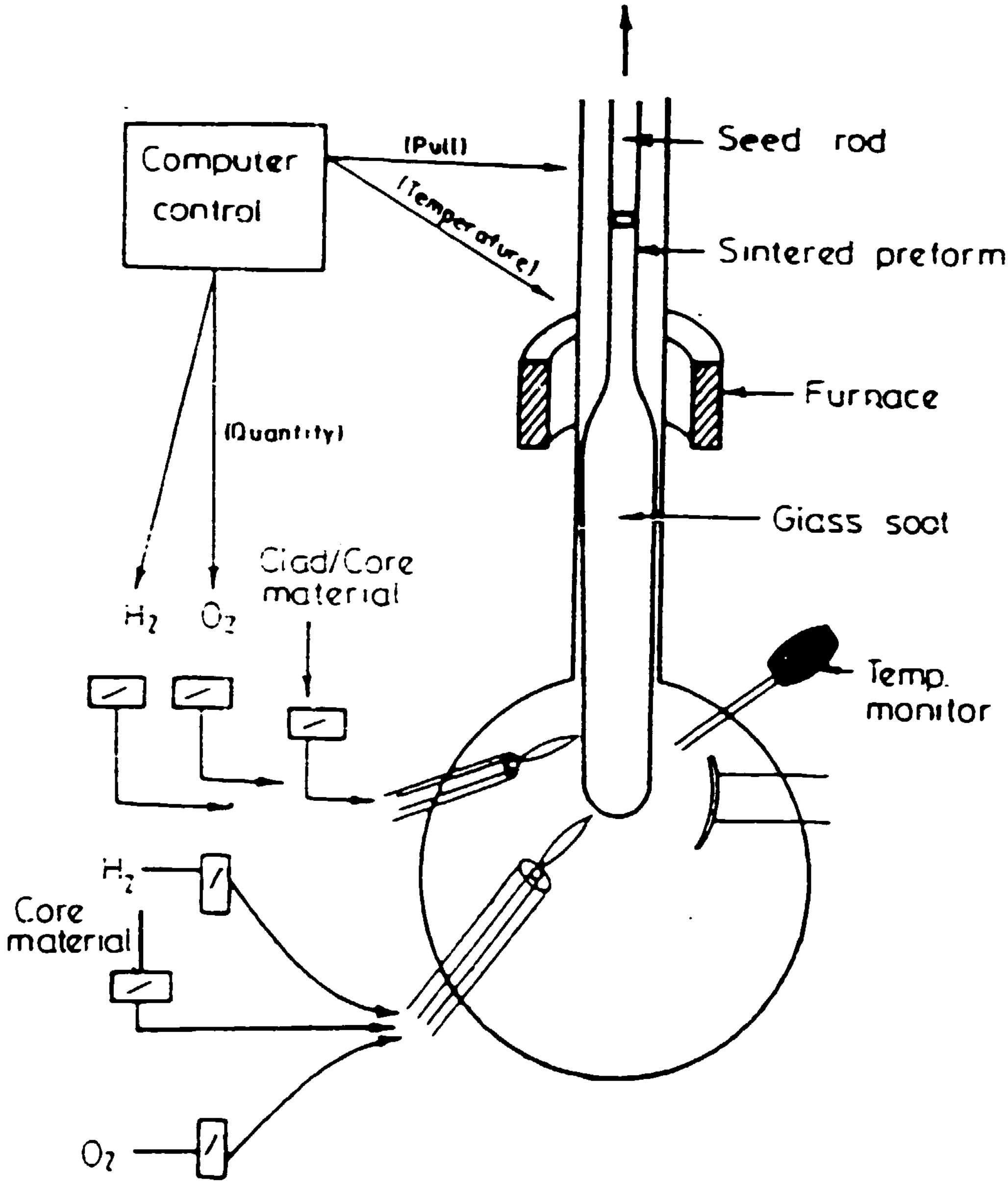


FIG. 9·3. Vapour axial deposition process

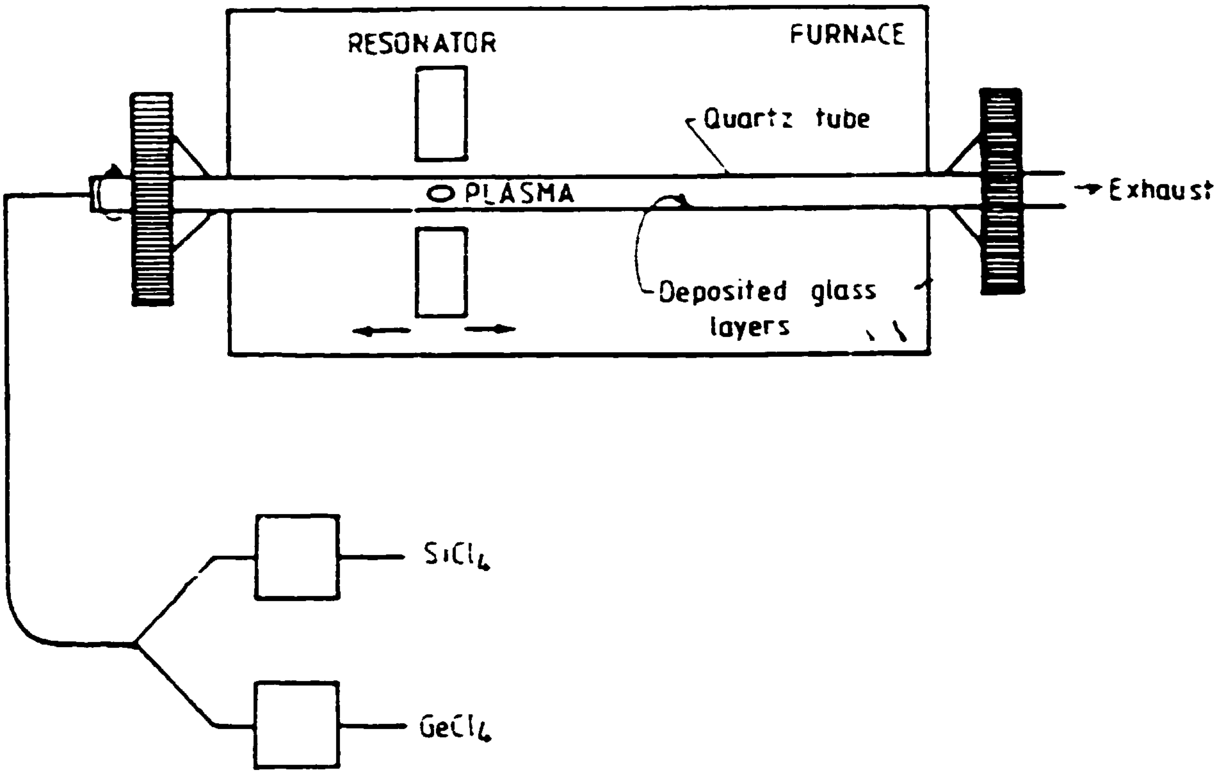


FIG 9·4. Plasma chemical vapour deposition process

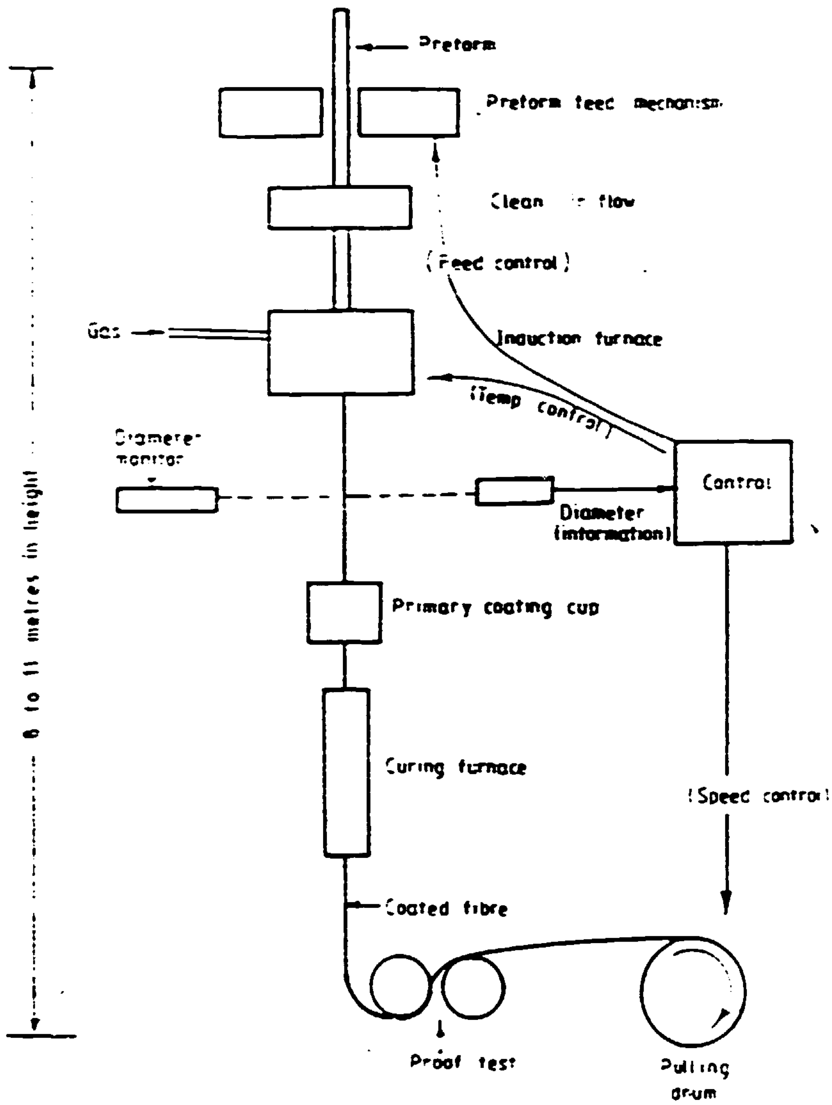


FIG. 9·5 Working of fiber draw tower

Table 9.6

Raw Materials etc. required for production of
25,000 Km of optical fibres by MCVD process

	Item	Qty. Reqd. Unit	Qty	Unit Cost US$	Total Cost US$ (000)
1.	Substrate (quartz) tube	Kg	2,250	222.22	500
2.	Exhaust Tube	Kg	625	48.00	30
3.	Silicon Chloride	Kg	2,375	29.47	70
4.	Ge Chloride	Kg	100	350.00	35
5.	PO Chloride	Kg	25	60.00	2
6.	Freon	litres	1,875	2.67	5
7.	Chlorine	litres	312,500	0.08	25
8.	Helium	litres	875,000	0.34	300
9.	Argon	Cu.m.	12,500	2.00	25
10.	Hydrogen	Cu.m.	87,500	0.11	10
11.	Oxygen	Cu.m.	150,000	0.33	50
12.	U.V.Acrylate	Kg	3,750	226.67	850
	Total				1,902
	Per Km of fibre				0.08

Thus the raw material cost works out to about 80 US$ per Km or 0.8 US Cent per meter of optical fibre.

Table 9.7

Plant & Machinery required for an annual Production of about 25,000 Km of optical fibres per annum

	Item	Qty. Reqd. (no.)	Unit Cost US$	Total Cost US$ (000)
A:	Laboratory for testing raw materials	Lot		40
B:	Instruments for Fibre testing			
1.	Optical Time Domain Reflectometer	1		
2.	Geometry Test set	1		
3.	Mode Field Dia test set	1		
4.	Chromatic dispersion test set	1		
5.	Attenuation test set	1		
6.	Others	Lot		
	Total B			400
C:	Production Machinery			
1.	MCVD Lathes	6	100,000	600
2.	Fibre Draw Towers	2	200,000	400
	Total C			1,000
D:	Reels,Drums,carriages etc			400
E:	Total plant & Machinery (A to D)			1,840
F:	Infrastructure			
1.	Land	10000	1	10
1.	Buildings	2000	160	320
2.	Power supply & standby	2000	32	64
3.	Gas Storage Tanks	12	5,000	60
4.	Water Supply	lot		10
5.	Ventilation	lot		10
6.	Environmetal protection	lot		200
	Total F			674
	Total investment required (E+F)			2,514

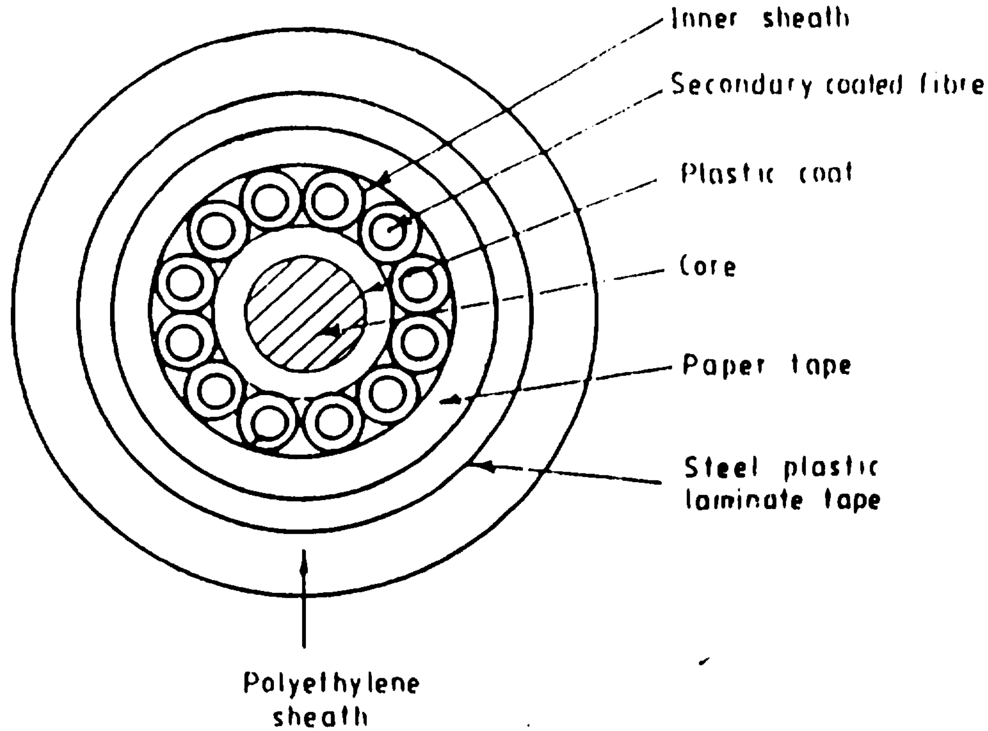


FIG. 9·8. Cross section of an optical fiber cable with Layer structure

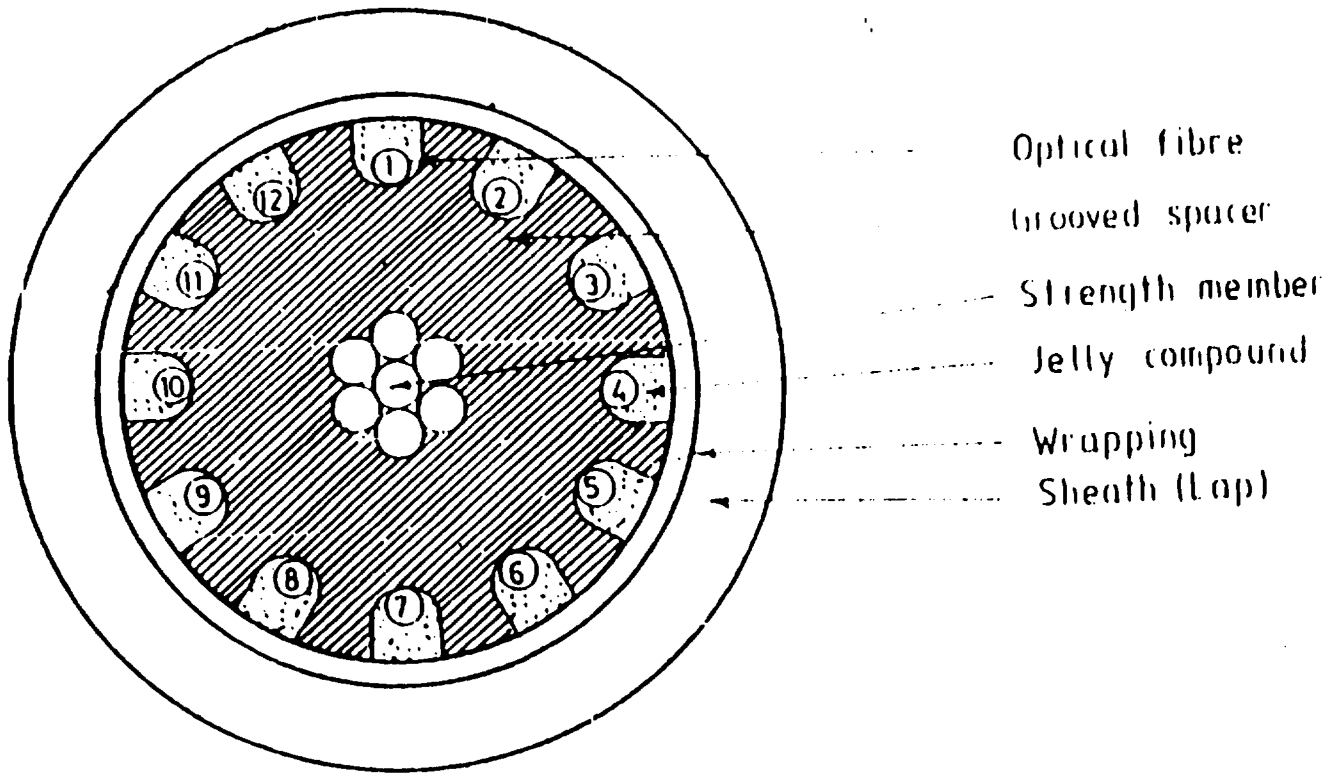


FIG. 9·9 Cross section of an optical fibre cable with tight jacket in V-groove structure

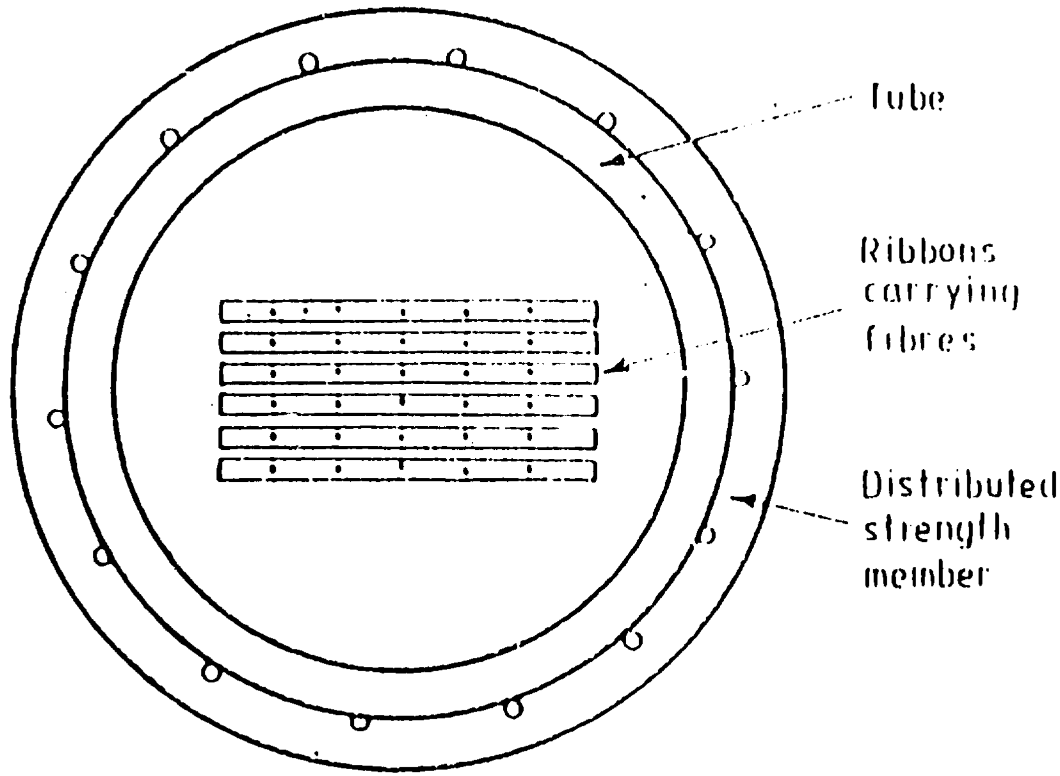


FIG. 9·10 . Cross section of an optical fibre cable with Ribbon structure

CHART 9.8

PROCESS FLOW FOR MANUFACTURE OF METALLESS OPTICAL FIBRE CABLES WITH TIGHT JACKETTING IN V-GROOVE STRUCTURE FROM BOUGHT OUT FIBRES

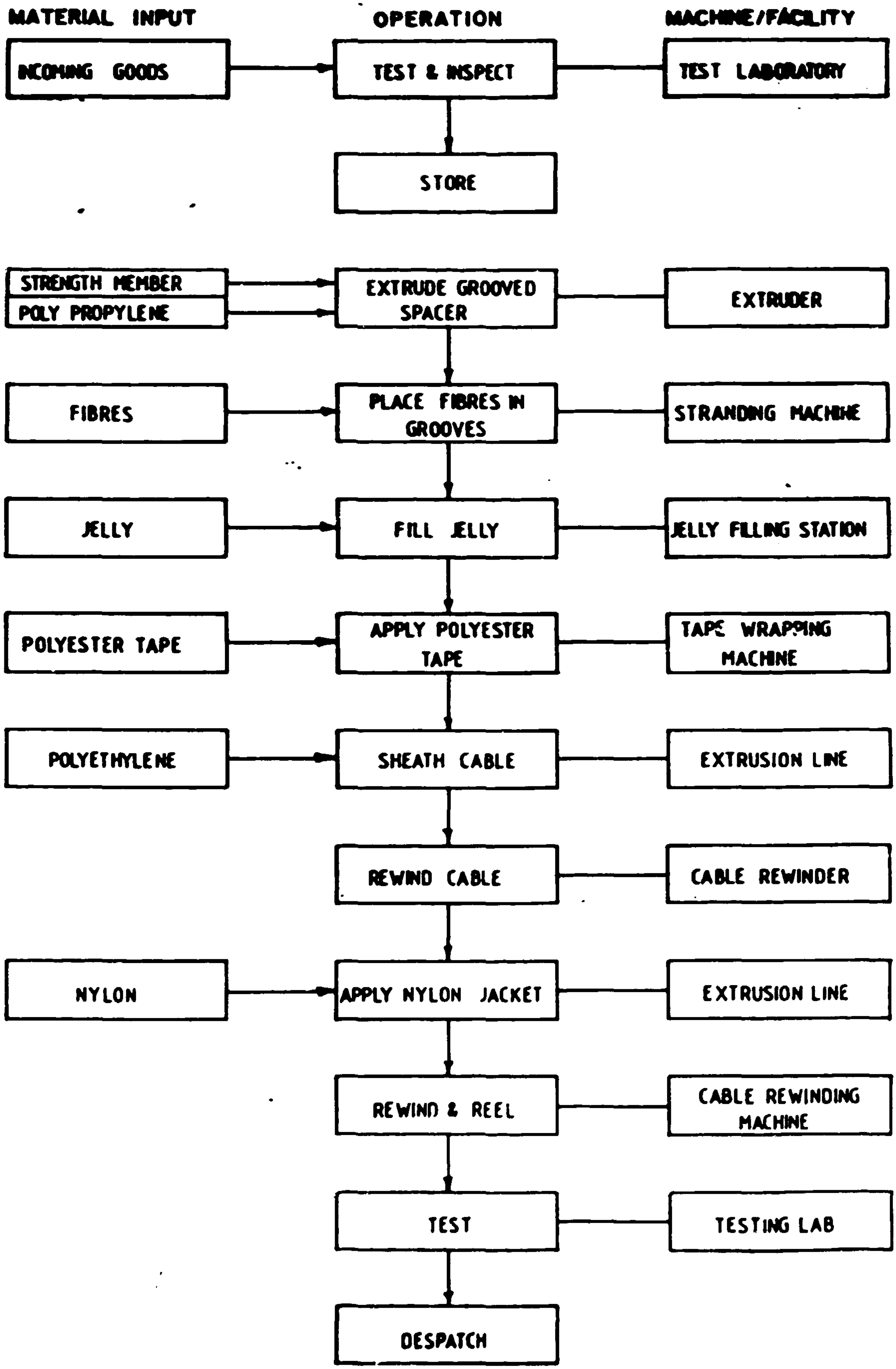


Table 9.12
Raw Materials etc. required for production of
2,500 sheath Km of metalless optical fibre cables
with an average of 10 fibres each

Item	Unit	Qty. Reqd. Reqd. Qty	Unit Cost US$	Total Cost US$ (000)
1. Optical fibre	Km	30,000	0.10	3
2. Strength Member (FRP)	Kg	31,250	24.00	750
3. Polypropylene	Kg	37,500	3.33	125
4. Filling Jelly	Kg	25,000	4.00	100
5. Polyester Tape	Kg	2,500	16.00	40
6. High Density Polyethelene	Kg	75,000	1.67	125
7. Nylon	Kg	43,750	22.86	1,000
Total				2,143

Thus the raw material costs work out to about 2,143/2.5 = 856 US$ per Km or 86 US cents per meter.

Table 9.13

Plant & Machinery
required for an annual production of about 2000 Sheath
Kilometers of optical fibre cables of average 10 fibres each

Sl No.	Item	Qty. Reqd. (no.)	Unit Cost US$	Total Cost US$ (000)
A:	Inward goods inspection (other than fibres):			
1.	Melt flow index tester	1		
2.	VISIO meter	1		
3.	Colour analyser	1		
4.	Differential Scanning Calorimeter	1		
5.	Others	Lot		
	Total A			100
B:	Instruments for Fibre testing			
1.	Optical Time Domain Reflectometer	1		
2.	Geometry Test set	1		
3.	Mode Field Dia test set	1		
4.	Chromatic dispersion test set	1		
5.	Attenuation test set	1		
6.	Others	Lot		
	Total B			400
C:	Production Machinery			
1.	Fibre rewinder	1		100
2.	Cable Rewinder	1		200
3.	Extrusion Line no 1	1		680
4.	Extrusion Line no 2	1		640
5.	Stranding & filling line	1		680
	Total C			2,300
D:	Reels,Drums,carriages etc			200
E:	Finished Goods inspection			
1.	Walk-in Environmental chamber	1		
2.	Torsion tester	1		
3.	Impact tester	1		
4.	Crash tester	1		
5.	Flexibility tester	1		
	Total E			400
F.	Total plant & Machinery (A to E)			3,400

Table 9.13 (Continued)

Plant & Machinery
required for an annual production of about 2000 Sheath
Kilometers of optical fibre cables of average 10 fibres each

Item		Qty. Reqd. (no.)	Unit Cost US$	Total Cost US$ (000)
G:	Infrastructure			
1.	Land	10,000 Sq m	1	10
2.	Buildings	2,000 Sq m	160	320
3.	Power supply & standby plant			64
4.	Compressed air supply			16
5.	Chilled water			20
6.	Ventilation			20
	Total G			450
H.	Total investment required (F+G)			3,850

Chapter 10

Telephone sets

10.1 Introduction

Telephone instrument, though forming only a small fraction of the total cost of the PSTN, still constitutes a substantial investment. It is also the most visible part of the network. Its production from bought out components is comparatively simple and cost effective even at comparatively small volumes. It can therefore form the nucleus in a small way of the local production of telecommunications equipment in many small developing countries.

10.2 Block diagram and functional description

Figure 10.1 gives a simple block diagram of a modern electronic telephone instrument. It has the following functional units:

a) Line switch : It operates by the weight of the handset incorporating the transmitter and receiver. When the hand set rests on the hook, the switch disconnects the dial and the speech circuit from the exchange line. When the hand set is lifted it connects them to the line.

b) Tone Ringer : On receipt of Ringing signal from the exchange, a ringing tone generator produces an output signal that drives an electoacoustic transducer. which emits the alerting tone.

c) The electronic dial generates either the dual tone multi-frequency or decadic pulses. A set may be equipped with one or the other or both with a common push button pad and a switch to change over from one to the other.

d) An integrated active network for coupling and decoupling the transmit and receive speech signals, for transmission on a two wire line, amplifying the transmitter output and sending it on the line, amplifying the receive speech signal and feeding it to the receiver.

e) Electro accoustic transducers serving as transmitter, receiver and ringers.

Above is the functional description of a basic telephone set used by a large majority of the subscribers. There are many other models with various features like hands free dialling. loud speaking, memory and abbreviated dialing etc.

10.3 Manufacturers of Telephone Instruments

Apart from all the major international manufacturers of telecommunication equipment, telephone instruments are being manufactured by a very large number of others, both on small and large scale, many of them in some of the developing countries.

10.4 Prices

The prices and quality of telephone instruments vary very widely. Quality wise, there are sets fully meeting the CCITT transmission standards and high reliability with MTBF of 10 years or more and there are others with poor transmission quality and a rather poor record of reliability. In general, a basic but quality electronic instrument meeting the CCITT transmission standards and a satisfactory level of reliability is quoted at around 25 US$.

10.5 Components required for production of an electronic telephone instrument

Table 10.2 gives a list of various components going into the production of a telephone set and typical prices for the same.

10.6 Process flow chart

Chart 10.3 indicates the process flow for assembly and testing of the telephone sets from bought out components.

10.7 Plant and machinery for production of telephone instruments from bought out components

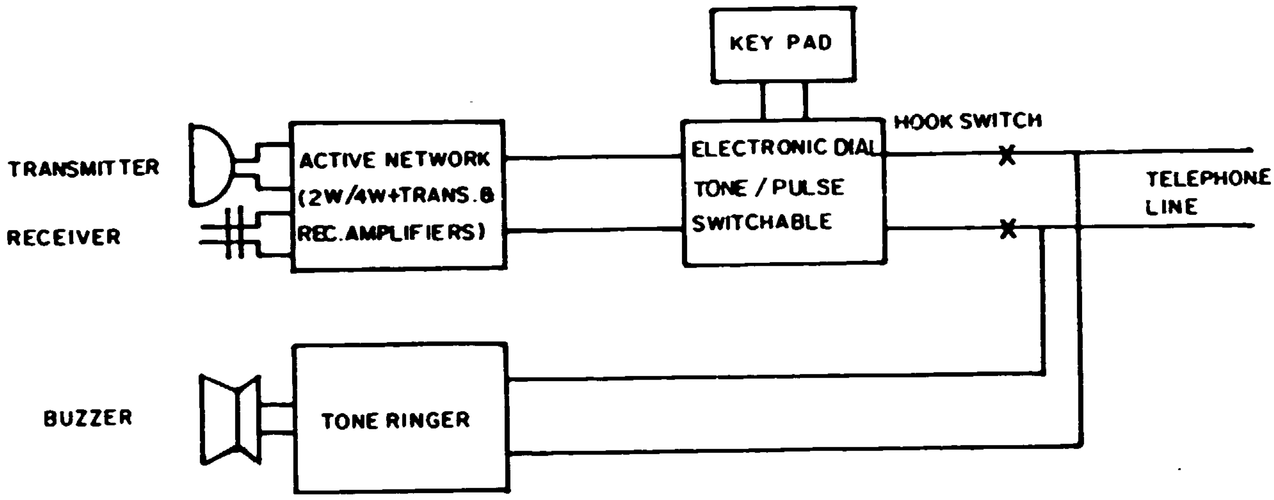
Table 10.4 gives a list of various machines, jigs, tools and testers required for assembly and testing of telephone instruments from bought out components with manual operations as far as possible, except where quality and reliabilty calls for automation, e.g. use of a wave soldering machine rather than hand soldering.

10.8 Economic level of production

With a reliable supply back up of components, an assembly plant could be economic for an annual production of about 50,000 to 100,000 sets. Production of some of the moulded components could become economic at an annual production of 100,000 to 200,000 sets.

Annexed:

Figure 10.1	Block Scematic of a basic electronic telephone
Table 10.2	Component requirements for Decadic Pulse/DTMF switchable telephone instrument.
Chart 10.3	Process flow chart for assembly and testing of an electronic telephone instrument from bought out components.
Table 10.4	Requirements of machines,jigs and tools for assembly & testing of electronic telephone from bought out components.



BLOCK SCHEMATIC OF AN ELECTRONIC TELEPHONE

FIGURE 10.1

Table 10.2

COMPONENT REQUIREMENTS PER SET
TELEPHONE INSTRUMENT DTMF/DIAL PULSE SWITCHABLE

Components	TYPES	qty no.	Price US$	per	Total/set US$	Total/set %
1. Capacitors, Metalized Plastic Film	10	12	50	/000	0.60	4.58
2. Capacitors, Electrolytic Aluminium	4	6	80	/000	0.48	3.66
3. Cords, Hand set, coiled	1	1	500	/000	0.50	3.82
4. Cords, Instrument, Straight	1	1	300	/000	0.30	2.29
5. Diodes	5	9	25	/000	0.23	1.72
6 FET	1	1	100	/000		
7. Hook Switches	1	1	100	/00	1.00	7.63
8. Housing Parts Set of 13	1	1	2.5	/set	2.50	19.08
9. IC's Dialler	1	1	500	/000	0.50	3.82
10.IC's Speech	1	1	1000	/000	1.00	7.63
11.IC's Ringer	1	1	500	/000	0.50	3.82
12.Keybooard Push button	1	1	100	/00	1.00	7.63
13.PCB's Single layer	1	1	600	/000	0.60	4.58
14.Quartz CrystalOscillator	1	1	300	/000	0.30	2.29
15.R. Button	1	1	200	/000	0.20	1.53
16.Resistors, Metal film (o.25w)	28	28	6	/000	0.17	1.28
17.Resistors, Metal film (0.50w)	2	2	6	/000	0.01	0.09
18.Transducers, Transmitter	1	1	850	/000	0.85	6.49
19.Transducers, Receiver	1	1	850	/000	0.85	6.49
20.Transducers, Ringer	1	1	200	/000	0.20	1.53
21.Transistors	4	5	120	/000	0.60	4.58
22.Varistors	1	1	120	/000	0.12	0.92
23.Miscellaneous set of screws,washers terminals,rubber shoes etc	1	1	0.6	/set	0.60	4.58
Total/set	70	79			13.11	

CHART 10.3

TYPICAL PROCESS FLOW CHART FOR PRODUCTION OF ELECTRONIC TELEPHONE SETS (DTMF / DP SWITCHABLE)

(ASSEMBLY FROM BOUGHT COMPONENTS)

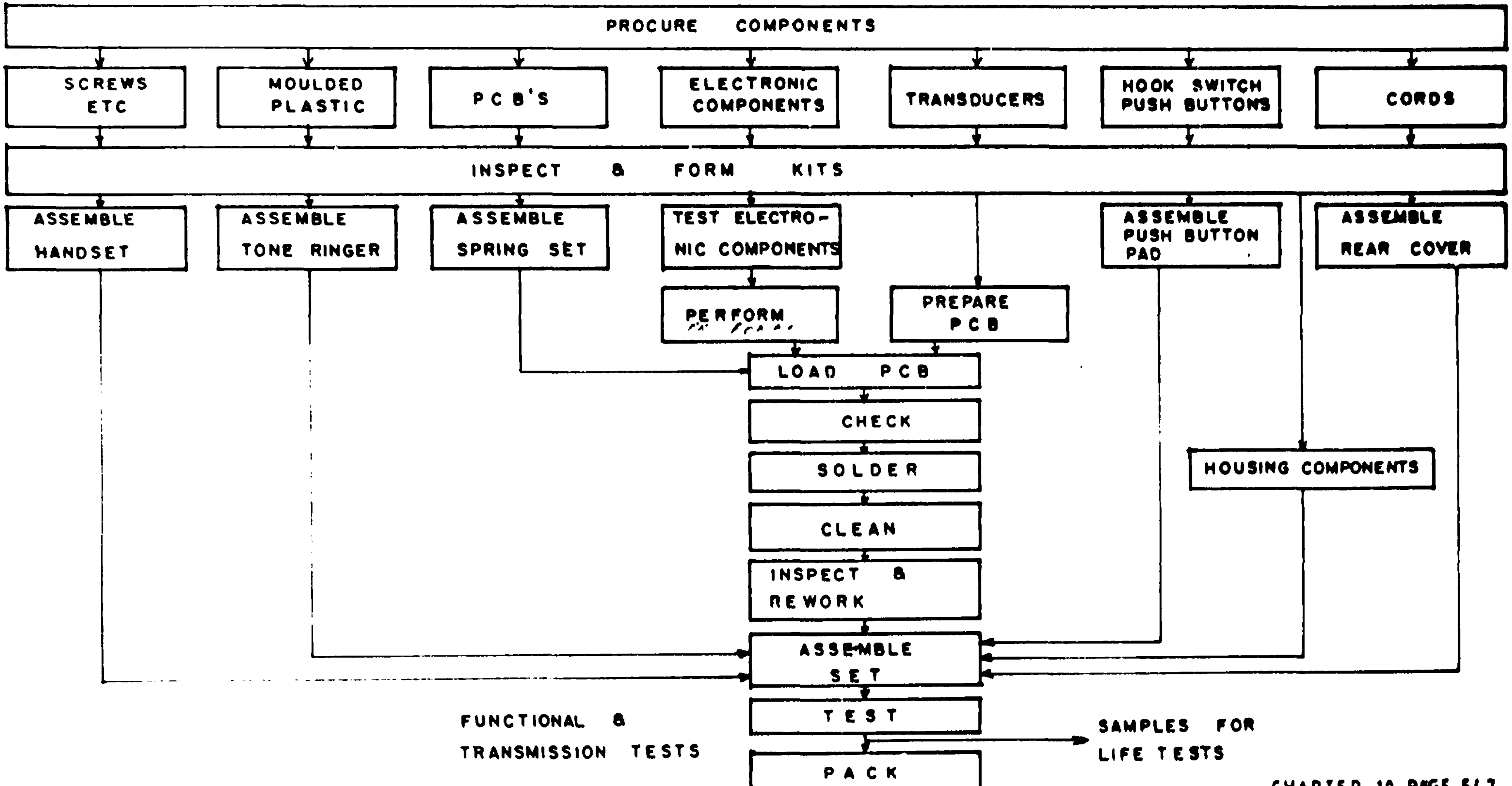


Table 10.4

PRODUCTION EQUIPMENT REQUIREMENTS
TELEPHONE INSTRUMENT DTMF/DIAL PULSE SWITCHABLE
ASSEMBLY LINE ONLY, ALL COMPONENTS BOUGHT OUT

Following table gives the requirements of machines, tools, jigs and testers for a pure assembly plant with manual operations as far as possible, with an annual production of 100,000 to 200,000 sets on a single shift basis. All components have been assumed to be bought out as per the list at table 10.2

Machines & Accessories	Typical Qty no.	prices unit US$	total US$
A: Hand preparation of electronic components			
1. Cutting & bending jig & tools for axial components belted	1	200	200
2. Cutting & bending jig & tools for components, singles	1	100	100
3. Cutting device for transistors	1	200	200
4. Straightening device for IC's	1	200	200
5. Counting device for components belted	1	200	200
6. Wire link cutter	1	50	50
7. Component testing & preparation tables	2	500	1,000
B: Componet insertion in PCB			
1. Conveyorised stuffing stations with stuffing jigs	10	800	8,000
C: Wave Soldering			
1. Wave soldering machine 12" size with cleaning & cutting facility	1	15,000	15,000
2. Soldering frames for above	10	50	500
3. Inspection & Repair table	1	200	200
4. Soldering iron (temp. controlled)	1	50	50
D: Instrument Assembly			
1. Conveyorised Telephone set Assembly stations	10	800	8,000
2. Pneumatic Screwdrivers	6	100	600
3. Soldering irons	4	50	200
Total carried forward			34,500

Table 10.4 (continued)

PRODUCTION EQUIPMENT REQUIREMENTS
TELEPHONE INSTRUMENT DTMF/DIAL PULSE SWITCHABLE
ASSEMBLY LINE ONLY, ALL COMPONENTS BOUGHT OUT

Machines & Accessories	Typical Qty no.	prices unit US$	total US$
Brought forward			**34,500**
E: Testing, labelling & packing			
E: Test equipment			
1. Digital LCR meter	1	1,000	1,000
2. Digital capacitance meter	1	1,000	1,000
3. Digital precision ohmmeter for low resistance measurement	1	1,500	1,500
4. Insulation resistance tester	1	1,000	1,000
5. High voltage test equipment	1	1,500	1,500
6. IC,Transistors & Diodes tester	1	25,000	25,000
7. In-circuit board tester taking upto 2048 points	1	15,000	15,000
8. Key board tester	1	10,000	10,000
9. Hook Switch life tester	1	1,000	1,000
10. Cord life tester	1	1,000	1,000
11. Ringer life tester	1	1,000	1,000
12. Tone Pulse Telephone analyser	1	5,000	5,000
13. Telephone tester with accessories including testing of transducers	1	35,000	35,000
14. General purpose multi-meters	2	500	1,000
15. Testing & labelling table	1	500	500
Total			135,000
Infrastructure: Land, building, electric power, dust filtering, office equipmet & furniture			250,000
Total initial investment			385,000

Chapter 11

Components

11.1 Introduction

11.1.1 A broad analysis of various types of components going into the production of a few of the important systems forming part of National Public Switched Telecommunication networks has been undertaken in chapters 4, 7, 8, and 10. The analysis, though necessarily limited to only a few systems, gives some idea of the very wide variety and range of components going into the telecommunication systems. Components generally appear to contribute about 30% of the total cost of production of the systems, actual figures varying somewhat from system to system. The cost of components is thus an important issue to be considered towards reduction of the cost of networks.

11.1.2 To bring the issues involved into better focus an attempt has been made to draw up a fairly comprehensive list of different types of components and classify them on a scale of 1 to 5 for the frequency of use and complexity of production processes. The results are presented in Annex 11.1

In regard to frequency of use, 1 represents infrequent use in a few systems, 5 represents use in large numbers. Klystrons are an example of components classified 1 and resistors, capacitors, integrated circuits and accoustic transducers are typical examples of class 5.

In regard to complexity of production processes, 1 represents very simple production processes while 5 represents highly complex and closely controlled ones. Moulded parts are an example of 1 and the integrated circuits of 5.

In either case, the classification represents basically a subjective judgement of the editors. There could be some differences of opinion in regard to the classification.The editors however believe that the table will still be found useful as a starting point for the deliberations of the conference in respect of strategies for production of components in developing countries.

11.2 Sources of supply for components

The variety of components calls for a large variety of raw materials and processes for their manufacture. A very large number of companies in different countries are manufacturing components. Almost all the major manufacturers of telecommunication equipments have component divisions. They manufacture components partly for their own use and also sell internationally. There are also a fairly large number of independent manufacturers producing only components. Many specialize in specific types. Among the developing countries, Korea and Taiwan have built up a major electronics components industry. They also have a number of companies specializing in projects for manufacture of the more common components. They undertake to design plants and supply the manufacturing equipment.

Electronic component market which also embraces the components for telecommunications is a multi-billion dollar one. With such a large market a number of international and national directories and catalogues of electronics components are published by independent publishers. and industry and business associations. A number of magazines and journals catering to the electronics components and systems industry are also being published. In addition, most of the major manufacturers publish catalogues giving the specifications and operating characteristics of their products and prices. A number of business houses specialize in procurement and supply of components. They also undertake to form component kits for systems on the basis of bill of materials prepared by the designer or manufacturer.

Annex 11.2 gives a very brief illustrative list of international directories of electronic components.

11.3 Typical processes, cost of raw materials and plant and machinery for production of components

Purely for purposes of illustration chapters 12 to 15 present typical process flow charts, raw material and plant and machinery required for 4 of the most frequently used components in telecommunication systems namely carbon metal film resistors, ceramic capcitors, printed circuit boards and integrated circuits. The information is necessarily somewhat sketchy and figures of costs purely illustrative based on budgetary quotes. They however serve to give an idea of the complexity of processes and the order of investments involved.

Annexed:

Annex 11.1	**List of components classified as above**
Annex 11.2	**A brief list of international directories of electronic components.**

Annexed

Annex 11.1 List of components classified as above

ANNEX 11.1

An alphabetical list of frequently used components in systems going into telecommunication networks also indicating on a scale of 1 to 5 the comparative frequency with which the component is used and the complexity involved in its manufacture from raw materials

Sl no.	Name of component	Rating on a scale of 1 - 5: Frequency of use	Complexity of production
1.	Acoustic Signalling devices, buzzers	5	2
2.	Acoustic transducers	5	[illegible]
3.	Backplanes, motherboards	5	2
4.	Batteries,		
	lead acid,maintenance free	3	2
	rechargeable Ni Cd	1	3
5.	Bubble Memory devices	1	4
6.	Cable glands,locknuts,stopping plugs	1	2
7.	Cable markers, sleeves, ties	5	1
8.	Capacitors:		
	ceramic	5	2
	chip	3	3
	electrolytic	3	2
	high voltage	1	2
	metallised paper film	1	2
	mica	1	2
	plastic(metallised polyesterine etc)	5	2
	precision	1	4
	radio frequency	3	3
	sub-miniature	1	3
	tantalum	3	3
	trimmer	2	[illegible]
	variable	2	3
9.	Card frames	5	[illegible]
10.	Connectors		
	circular	1	[illegible]
	coaxial	4	[illegible]
	flat cable	3	[illegible]
	insulation displacement	4	[illegible]
	optical fibre	4	[illegible]
	printed circuit board	5	[illegible]
	rack and panel	4	[illegible]
	rectangular	4	[illegible]
	radio frequency interference shielded	2	[illegible]
	sub-miniature	1	[illegible]
	surface mount	1	[illegible]
11.	Contactors	2	[illegible]
12.	Counters	1	[illegible]
13.	Crystals, oscillators	3	[illegible]
14.	Delay Lines	3	[illegible]

ANNEX 11.1 (continued)

An alphabetical list of frequently used components in systems going into telecommunication networks also indicating on a scale of 1 to 5 the comparative frequency with which the component is used and the complexity involved in its manufacture from raw materials

Sl no.	Name of component	Rating on a scale of 1 - 5 Frequency of use	Complexity of production
17.	Diodes		
	Gunn effect	1	4
	light emitting	3	3
	low power	4	3
	power rectifiers	2	3
	varactors	2	3
	zener	3	3
18.	Display controllers	2	5
19.	Displays		
	alpha numeric (LCD)	2	4
	digital	2	4
	light emitting diode	2	3
20.	Fans	2	2
21.	Filters		
	Ceramic	2	3
	Crystal	2	3
22.	Fuse holders	2	2
23.	Fuses	2	2
24.	Headphones	2	2
25.	Heat sinks	2	2
26.	Hybrid circuits	5	3
27.	Impatt oscillators	2	3
28.	Inductances		
	chokes & coils	3	2
	chip	1	4
29.	Integrated circuits		
	Application specific (ASICS)	3	5
	Custom	2	5
	Digital	5	5
	Linear/analogue	5	5
	Microwave	2	5
	General	4	5
30.	Interference filters	3	2
31.	Keyboards	5	3
32.	Klystrons	1	4
33.	Knobs & dials	4	1
34.	Lamps	3	3
35.	Laser diodes	2	5
36.	Magnetic cores	5	3
37.	Mechanical parts, racks, cabinets, panels etc	5	2
38.	Microphone capsules	5	2

ANNEX 11.1 (Continued)

An alphabetical list of frequently used components in systems going into telecommunication networks also indicating on a scale of 1 to 5 the comparative frequency with which the component is used and the complexity involved in its manufacture from raw materials

Sl no.	Name of component	Rating on a scale of 1 - 5: Frequency of use	Complexity of production
39.	Microwave components		
	passive	2	5
	semi-conductor	2	4
40.	Moulded plastic parts	5	1
41.	Panel meters	3	3
42.	Permanent magnets	5	2
43.	Photodiodes	3	4
44.	Photoelectric cells & tubes	2	3
45.	Plugs, sockets & Jacks	5	3
46.	Potentiometers		
	trimmer	5	3
	wire wound	2	3
47.	Printed Circuit Boards	5	3
48.	Relays		
	coaxial	1	4
	miniature	5	4
	reed	3	3
	solid state	2	3
49.	Resistor networks	4	3
50.	Resistors		
	carbon film	2	2
	composition	1	2
	high voltage	1	2
	metal film	5	2
	metal oxide	1	2
	precision	1	3
	variable	3	3
	voltage dependent	1	3
	wire wound	4	3
51.	Sockets		
	IC's	4	3
	LED's	3	3
52.	Solar cells	2	4
53.	Stepper motors	2	4
54.	Surge arrestors	5	4
55.	Switches		
	DIP	2	3
	Key	3	2
	membrane/foil	5	3
	mercury	2	3
	pushbutton	2	3
	reed	2	3
	rotary	2	3
	slide	2	3
	sub-miniature	1	4
	toggle	2	2

ANNEX 11.1 (Continued)

An alphabetical list of frequently used components in systems going into telecommunication networks also indicating on a scale of 1 to 5 the comparative frequency with which the component is used and the complexity involved in its manufacture from raw materials

Sl. no.	Name of component	Rating on a scale of 1 - 5: Frequency of use	Complexity of production
56.	Terminals	5	2
57.	Thyristors	2	4
58.	Transformers		
	Auototransformers	1	2
	constant voltage	1	2
	current	1	2
	hybrids	5	2
	isolation	1	2
	power	3	2
	pulse	3	2
	toroidal	2	2
	variable	1	2
59.	Transistors		
	chip	3	4
	Darlington	1	4
	field effect	1	4
	low power	4	4
	power	3	4
	radio frequency	3	4
60.	Triacs	3	4
61.	Tubes		
	Travelling wave	1	5
62.	Wave guides & components	3	4

ANNEX 11.2

A brief illustrative list of international/national directories of electronic component producers and agents etc

Sl no	Publishers	Name of publication
1.	Elsevier Advanced Technologies	International Electronics Directory a) The guide to European Manufacturers, Agents Applications b) Who's Who in Electronics (USA)
2.	Electronic Industries Association of Japan	Electronic Parts Catalogue
3.	Hearst Business Communications Inc.	IC Master

Chapter 12

Outline of production process, raw material, plant and machinery and manpower requirements for production of 250 million pieces a year of Resistors, carbon and metal film

12.1 Introduction

As seen in the analysis of component requirements for various typical telecommunications systems, a very large number of resistors carbon or metal film go into these systems. The annual consumption runs into billions of peices. The quoted prices vary between 12 to 20 US$ per thousand pieces.

12.2 Production process

Chart 12.1 gives a somewhat simplified process flow for production of these resistors from ceramic rods and other raw materials. The repeatability and reliability requirements call for some automation ano in-process testing and control. Table 12.3 gives the requirements of machines and test equipment for an annual production of about 250 million pieces. on two shift basis. Table 12.4 gives the manpower requirements for this plant along with approx manpower costs in a developed and a developing country.

13.3 Raw material requirements

Table 12.2 gives the quantities and estimates of cost for 250 million pieces. about 50 million of carbon film and 200 million of metal film.

13.4 Observation

The cost of raw materials per thousand pieces works out to about 2 US$. The capital recovery factor for the plant and machinery for an assumed life of four years works out at about 1.3 US$. The manpower cost in a developing country is less than a dollar but substantially higher in a developed country.

Annexed:

Chart 12.1 :	Typical process flow for production of resistors, carbon and metal film.
Table 12.2 :	Raw material requirements for production of resistors, carbon and metal film
Table 12.3 :	Requirements of Plant & Machinery for an annual production of 250 million pieces of resistors, carbon and metal film, on two shift basis.
Table 12.4 :	Manpower requirements for annual production of 250 million pieces a year of carbon and metal film resistors, on two shift basis

CHART 12·1

TYPICAL PROCESS FLOW FOR PRODUCTION OF CARBON/METAL FILM RESISTORS

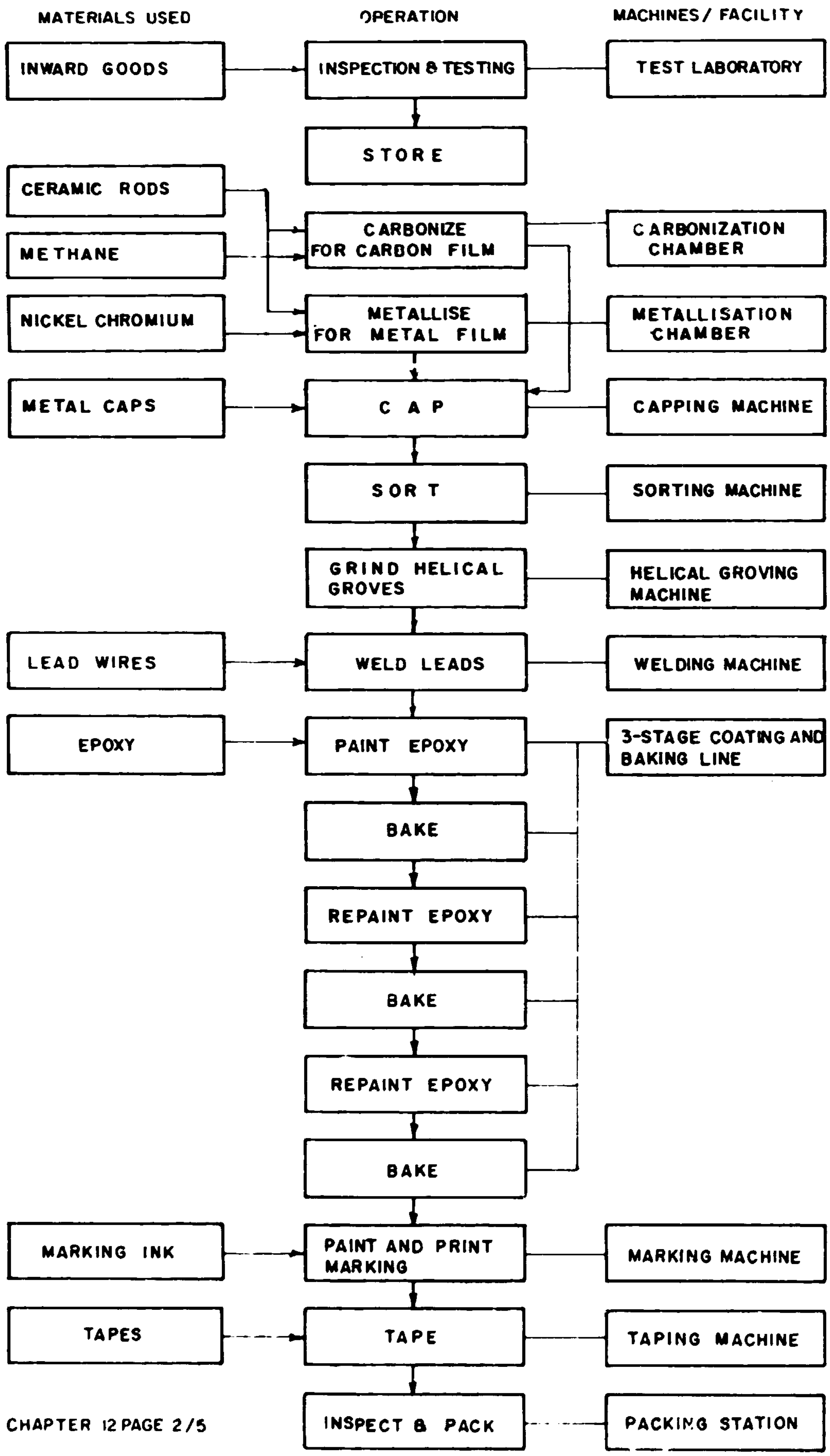


Table 12.2

Raw Materials etc. required for production of 250 Million carbon/metal film resistors

Item		Qty. Reqd. Unit	Qty	Unit Cost US$	Total Cost US$ (000)
1.	Ceramic Rods	Million	252	175/M	44.10
2.	CRC Caps	Million	504	102/M	51.41
3.	Tinned copper Wire	Tonne	40	3.2/Kg	128.00
4.	Methane	Kg			0.50
5.	Nickel Chromium Powder	Kg	250	600/Kg	150.00
6.	Epoxy Paint	Tonnes	40	1.7/Kg	68.00
7.	Paper Tape	Tonnes	30	1.4/Kg	42.00
8.	Marking Ink	Kg	2.5	10/Kg	0.03
	Total				484.03

Above is for a production of about 50 million carbon and 200 million metal film resistors

Cost of raw materials works out to about US$ 1.94 against an international selling price of about US$ 15 per thousand pieces.

Table 12.3

Plant & Machinery required for an annual Production of about 250 million carbon/metal film resistors per annum

	Item	Qty. Reqd. (no.)	Unit Cost US$	Total Cost US$ (000)
A:	Laboratory for testing raw materials	Lot		10
B:	Instruments for final testing			
1.	LCR meter	1		
2.	Insulation Tester	1		
3.	High Voltage Tester	1		
4.	Climatic Chambers	1		
5.	Noise tester	1		
	Total B			20
C:	Production Machinery			
1.	Carbonization chamber	1	15,000	15
2.	Metallization chamber	2	150,000	300
3.	Capping Machines	4	10,000	40
4.	Sorting Machines	3	12,000	36
5.	Helical grinding Machines	12	6,000	72
6.	Lead Welding Machines	8	12,000	96
7.	Epoxy coating & baking line	3	40,000	120
8.	Marking Machines	3	6,000	18
9.	Taping Machines	2	5,000	10
	Total C			707
D:	Total Machines & testers			737
E:	Infrastructure			
1.	Land	5000	5	25
2.	Buildings	1000	160	160
3.	Power supply & standby	lot	32	32
4.	Ventilation	lot		10
	Total E			227
	Total investment required D + E			964
	Capital recovery for a life of 4 years i.e. @ 33 per annum			322
	Capital recovery cost for 1000 pieces			1.288
		say US$		1.3

Table 12.4

Typical Manpower requirements for production of 250 million Resistors, carbon & metal film, in the plant as outlined in Table 12.3 and typical annual costs in a developed and a developing country.

A: Developed Country

Manpower requirements		no.	Annual costs in a developed country US$(000)	US$(000)
1.	Managers	1	60	60
2.	Technicians	3	40	120
3.	Quality Controllers	2	45	90
4.	Material controller	1	40	40
5.	Production Controller	1	45	45
6.	Supervisors	2	40	80
7.	Operators:			
	Carbonization/metallization	1	30	30
	Capping	4	30	120
	Sorting	4	30	120
	Grinding	4	30	120
	Welding	4	30	120
	Epoxy painting & marking	4	30	120
	Paper taping & packing	2	30	60
8.	Sales & Shipping	2	40	80
	Total :	35		1205
	Manpower cost per 1000 pieces :	US$ 4.82		

B: Developing country

Manpower requirements		no.	Annual costs in a developing country US$(000)	US$(000)
1.	Managers	1	5	5
2.	Technicians	3	3	9
3.	Quality Controllers	2	3.5	7
4.	Material controller	1	3	3
5.	Production Controller	1	4	4
6.	Supervisors	2	3.5	7
7.	Operators:			
	Carbonization/metallization	1	2	2
	Capping	4	2	8
	Sorting	4	2	8
	Grinding	4	2	8
	Welding	4	2	8
	Epoxy painting & marking	4	2	8
	Paper taping & packing	2	2	4
8.	Sales & Shipping	2	3.5	7
	Total :	35		88
	Manpower cost per 1000 pieces :	US$ 0.352		

Chapter 13

Outline of production process, raw material, plant and machinery and manpower requirements for production of 100 million pieces a year of Capacitors. Ceramic disk type

13.1 Introduction

As seen in the analysis of component requirements for various typical telecommunications systems. a very large number of ceramic capacitors go into these systems. The annual consumption runs into billions of pieces. The quoted prices vary between 20 to 30 US$ per thousand pieces.

13.2 Production process

Chart 13.1 gives a somewhat simplified process flow for production of these capacitors from basic raw materials. The repeatability and reliability requirements call for considerable automation and in-process testing and control. Table 13.3 gives the requirements of machines and test equipment for an annual production of about 100 million pieces. Table 13.4 gives the manpower requirements for working on two shift basis.

13.3 Raw material requirements

Table 13.2 gives the quantities and estimates of cost for one million pieces of capacitors.

13.4 Observation

The cost of raw materials per thousand pieces works out to about 2 US$. The capital recovery factor for the plant and machinery for an assumed life of four years works out at about 3 US$. The manpower cost in a developing country is comparable but substantially higher in a developed country.

Annexed

Chart 13.1	Typical process flow for production of capacitors. ceramic disc type.
Table 13.2	Raw material requirements for production of capacitors. ceramic disc type.
Table 13.3	Requirements of Plant & Machinery for an annual production of 100 million pieces of capacitors. ceramic disc type. on two shift basis.
Table 13.4	Manpower requirements for annual production of 100 million pieces a year of capacitors. ceramic disc type. on two shift basis

CHART 13.1

PROCESS FLOW CHART FOR PRODUCTION OF CAPACITORS , CERAMIC DISC TYPE

A. PRODUCTION OF CERAMIC DISC ELEMENTS

MATERIAL USED	PROCESS	MACHINE USED
METOLOSE, GLYCERINE, WATER	1. MIX & BOIL BINDING MIXTURE	BOILER / MIXER
	2. COOL	COOLING CHAMBER
CERAMIC POWDER	3. MIX BINDING MIXTURE & CERAMIC POWDER	FABRICATING MACHINE
	4. ROLL TO ADJUST PARTICLE SIZE	ROLLING MACHINE
	5. COOL	COOLING CHAMBER
	6. EXTRUDE TO 100 mm WIDE 0.1 TO 0.2mm THICK STRIPS	VACUUM EXTRUDER
	7. DRY & ROLL TOGETHER	DRYING CONVEYOR
	8. PUNCH DISCS OF APPROPRIATE SIZE	DISC FORMING MACHINE
	9. FIRE DISCS AT 1400 DEG. C TO SINTER	ELECTRIC KILN
	10. SEPERATE SINTERED DISCS	ULTRASONIC SEPERATOR
	11. DRY DISCS	CONVEYOR OVEN
	12. SORT OUT BENT OR UNSEPERATED DISCS	SORTING MACHINE
	COUNT & PACK CERAMIC DISC ELEMENTS	ELECTRIC WEIGHING MACHINE

CHART 13.1 (CONTINUED)

PROCESS FLOW CHART FOR PRODUCTION OF CAPACITORS, CERAMIC DISC TYPE

B: SILVER SCREEN PRINTING OF DISC ELEMENTS

MATERIAL USED	PROCESS	MACHINE USED
DISC ELEMENT SILVER SOLVENT	PREPARE SILVER PASTE & APPLY APPROPRIATELY TO DISC ELEMENT	AUTOMATIC PRINTER
	DRY	DRYER
	HEAT TO 800 C EVAPORATE RESIN & REDUCE SILVER OXIDE	ELECTRIC FURNACE
	COUNT & PACK	

C: ASSEMBLE CERAMIC CAPACITORS

MATERIAL USED	PROCESS	MACHINE USED
COPPER WIRE	FORM LEADS OF APPROPRIATE SIZE & SHAPE	AUTO LEAD FORMING MACHINE
SILVERED DISCS COPPER WIRE LEADS	ATTATCH LEADS TO DISCS	AUTO ASSEMBLING MACHINE
SOLDER & FLUX	SOLDER LEADS TO DISCS	AUTO SOLDERING MACHINE
ORGANIC SOLVENT COATING POLYMER POWDER (INSULATING)	PREPARE COATING PASTE	COATING MIXER MACHINE
SOLDERED DISCS COATING PASTE	APPLY COAT OF INSULATING POLYMER	AUTOMATIC COATING MACHINE
INK	PRINT APPROPRIATE MARKS	AUTOMATIC MARKING MACHINE
WAX	WAX ELEMENTS TO MAKE SURFACE GLOSSY & WATERPROOF	AUTOMATIC WAXING MACHINE
	TEST	AUTOMATIC TEST EQUIPMENT
	PACK IN BOXES OR ROLL	PACKING MACHINE

Table 13.2

Raw material requirements for production of 1 million pieces of Capacitors, Ceramic disc type

Sl. no.	Raw material particulars	Qty reqd (Kg)	Likely cost Unit Price US$	Total US$
1.	Adhesive paper(*1000 sq.m.)	13*	15	195.00
2.	Ceramic Powder	40.00	6.50	260.00
3.	Copper wire	150.00	3.25	487.50
4.	Durez(coating powder)	75.00	1.75	131.25
5.	Glycerine	2.25	2.50	5.63
6.	Ink	0.01	10.00	0.10
7.	Metclose(binding powder)	1.60	7.00	11.20
8	Paper tape	120.00	1.40	168.00
9.	Silver	2.00	200.00	400.00
10.	Silver paste solvent	0.03	1,700.00	51.00
11.	Solder	20.00	10.00	200.00
12.	Soldering flux	2.00	15.00	30.00
13.	Wax	20.00	3.75	75.00
	Total for one million pieces		US$	2,014.68

The raw material requirements work out to about US$ 2, against the selling price of finished product of about US $ 20 to 30 per 1000 pieces.

Table 13.3

Equipment,machines,tools & testers and infrastructure required for an annual production of about 100 million Capacitors, Ceramic disc type on two shift basis

Sl. no.	Machines,tools & testers	Qty reqd (no.)	Likely cost Unit Price US$	Total US$
A:	**Machines**			
1	Auto Assembly Machines	4	7,000	28,000
2	Auto Coating machines	2	5,600	11,200
3	Auto lead forming machines	4	8,000	32,000
4	Auto Marking Machines	2	6,700	13,400
5	Auto Printers	2	7,000	14,000
6	Auto Soldering Machines	2	12,000	24,000
7	Auto Testing Machines	4	15,700	62,800
8	Auto Waxing Machines	2	4,000	8,000
9	Boiling & Mixing Machine	1	2,100	2,100
10	Coating Mixer	1	2,300	2,300
11	Cooling chamber	1	4,500	4,500
12	Disc Forming Machine	1	5,400	5,400
13	Dryer for seperator	1	4,700	4,700
14	Dryer for printer	1	4,700	4,700
15	Drying conveyor for seperator	1	14,700	14,700
16	Electric Furnace (small)	1	23,500	23,500
17	Electric Kiln	1	84,000	84,000
18	Fabricating Machine	1	11,200	11,200
19	Ovens	2	6,700	13,400
20	Packing Machines	4	2,250	9,000
21	Roller Mixer	1	10,800	10,800
22	Sorting Machines	3	1,800	5,400
23	Ultrasonic Seperator	1	8,400	8,400
24	Vacuum Extruder	1	30,000	30,000
	Total A:			427,500

(continued)

Table 13.3(continued)

Equipment,machines,tools & testers and infrastructure required for an annual production of about 100 million Capacitors, Ceramic disc type on two shift basis

Sl. no.	Machines,tools & testers	Qty reqd (no.)	Likely cost Unit Price US$	Total US$
B:	**Accessories for machines**			
1.	For Kiln (lot)	1	19,000	19,000
2.	For disc former	30	450	13,500
3.	Screen for printer	200	35	7,000
4.	Templates	600	35	21,000
6.	For Ceramic Capacitor Assembly M/c (lot)	1	7,300	7,300
	Total B:			67,800
C:	**Test Equipment for Q.C.**			
1.	Temperature Coefficient chamber	1	28,000	28,000
2.	Puncture Test set	1	2,300	2,300
3.	Insulation resistance Tester	1	5,000	5,000
4.	LCR Meter 1Khz	1	4,000	4,000
5.	LCR Meter 1 Mhz	1	15,000	15,000
6.	Q meter	1	5,000	5,000
	Total C:			59,300

D: INFRASTRUCTURE

Sl. no.	Item	Area Sq.m.	Unit cost US$/Sq.m.	Total cost US$
1.	Land	5,000	2	10,000
2.	Building	500	100	50,000
3.	Electrical Installation	500	20	10,000
4.	Water supply	lot		5,000
5.	Environmental control	500	20	10,000
6.	Others	lot		20,000
	Total D:			105,000

(continued)

Table 13.3(continued)

Equipment, machines, tools & testers and infrastructure required for an annual production of about 100 million Capacitors, Ceramic disc type on two shift basis

SUMMARY OF INVESTMENT REQUIREMENT

	Item	US$
A:	Machines	427,500
B:	Accessories for machines	67,800
C:	Test Equipment for Q.C.	59,300
D:	Infrastructure	105,000
E:	Freight, Insurance, Installation & trial runs @ 40% of A+B+C+D	263,840
	Total estimated investment	923,440

Annual capital recovery factor for a life of 4 years with cost of money at 12% (@ 33%) 307,813

Per 1000 pieces on annual production of 100 million 3

Table 13.4

Typical Manpower requirements for production of 100 million Capacitors of Ceramic disc type, in the plant as outlined in Table 13.3 and typical annual costs in a developed and a developing country.

A: Developed Country

Manpower requirements	no.'s	Annual costs in a developed country US$(000)	US$(000)
1. Managers	2	60	120
2. Technicians	3	40	120
3. Quality Contollers	2	45	90
4. Material controller	1	40	40
5. Production Controller	2	45	90
6. Supervisors	3	40	120
Operators:			
7. Disc Element	16	30	480
8. Silver screen Printing	15	30	450
9. Capacitor Assembly	32	30	960
10. Sales & Shipping	2	40	80
Total :	78		2,250
Manpower cost per 1000 pieces :	US$ 25.5		

B: A developing country

Manpower requirements	no.'s	Annual costs in a developing country US$(000)	US$(000)
1. Managers	2	5	10
2. Technicians	3	3	9
3. Quality Contollers	2	3.5	7
4. Material controller	1	3	3
5. Production Controller	2	4	8
6. Supervisors	3	3.5	10.5
Operators:			
7. Disc Element	16	2	32
8. Silver screen Printing	15	2	30
9. Capacitor Assembly	32	2	64
10. Sales & Shipping	2	3.5	7
Total :	78		180.5

Manpower cost per 1000 pieces : US$ 1.8

Chapter 14

Outline of production process, and raw material, and plant and machinery requirements for fabrication of about 30,000 sq. m. of double sided, through hole, glass epoxy printed circuit boards

14.1 **Introduction**

As seen in the analysis of component requirements for various typical telecommunications systems, printed circuit boards are an essential input for the production of almost every module for every telecommunication system. Printed circuit boards are used to mount and interconnect the various components reliably. The annual consumption runs into millions of sq. meters of printed circuit boards. For simple small modules single sided boards are usual. For more elaborate ciruits, double sided ones are used. Multi layer boards are often employed for large circuits. In this chapter a brief outline of processes involved, and materials and machines and plant required for production of about 30,000 sq. meters of double sided boards has been attempted. Such boards are quoted at about US$ 125 per sq. meter.

14..2 **Production process**

Chart 14.1 gives a somewhat simplified process flow for production of these Printed circuit boards. The repeatability reliability and high precision call for a high level of automation and in-process testing and control. Table 14.3 gives the requirements of machines and test equipment for an annual production of about 140,000 sq. meters of these boards. It will be seen that the investment requirement is rather high even though only one machine of each type has been included.

14.3 **Raw material requirements**

Table 14.2 gives the quantities and estimates of cost for 1200 sq. meter of these boards to work out the cost per sq. meter.

13.4 **Observation**

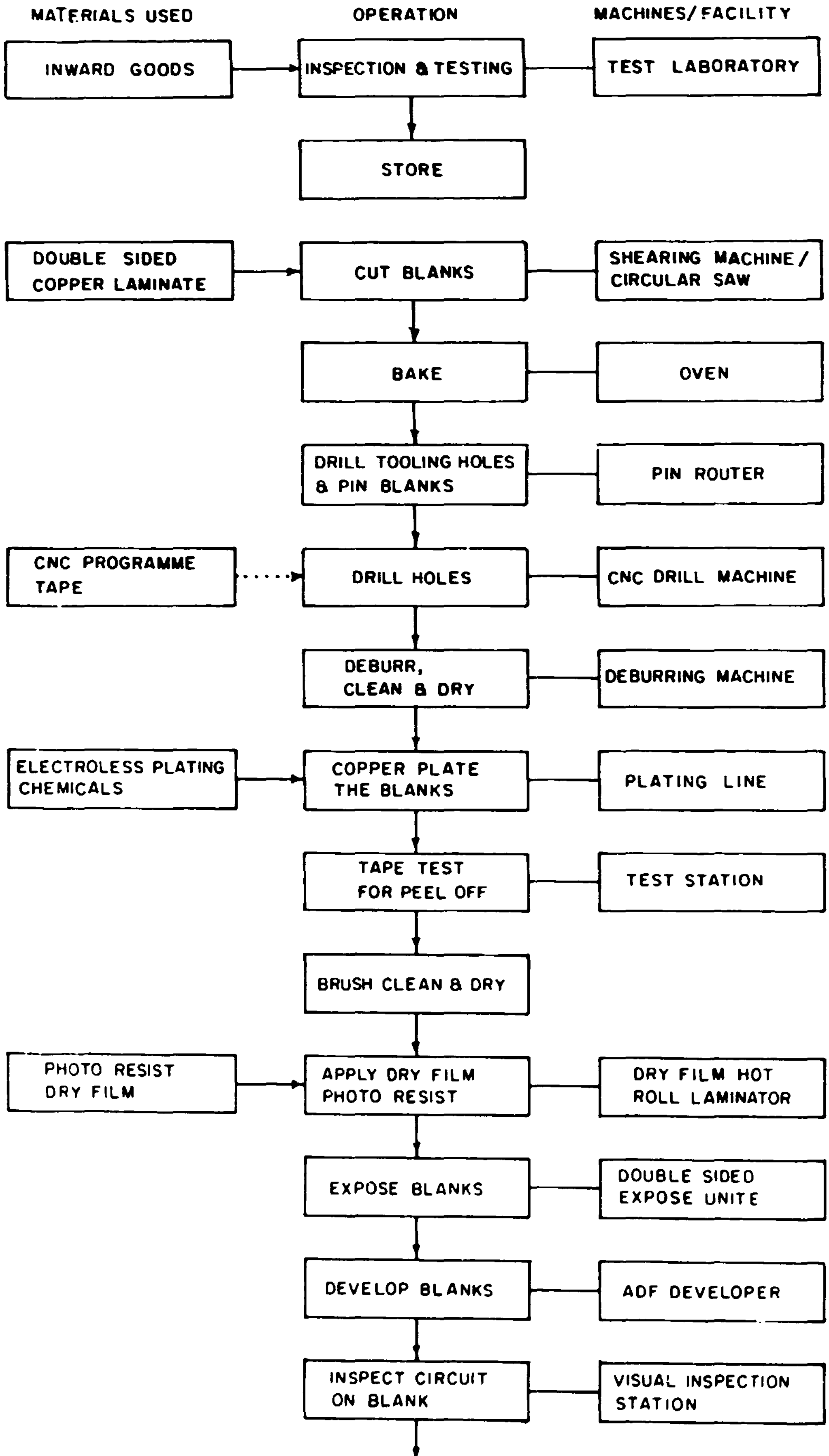
The cost of raw materials per sq. meter works out to about 73 US$ which is rather high for a finished product being quoted at US$ 125 per sq. meter. The capital recovery factor for the plant and machinery for an assumed life of four years works out at about 16 US$ per sq. meter.

Annexed:

Chart 14.1	**Typical process flow for production of double sided through hole printed circuit boards for professional equipment.**
Table 14.2	**Raw material requirements for production double side through hole PCB'S capacitors, ceramic disc type.**
Table 14.3	**Requirements of Plant & Machinery for an annual production of 30,000 Sq. meters of double sided boards.**

CHART 14·1

TYPICAL PROCESS FLOW FOR PRODUCTION OF DOUBLE LAYER PRINTED CIRCUIT BOARDS HOT AIR LEVELLED



CONTINUED SHEET 2

CHART 14·1 (Sheet 2)
TYPICAL PROCESS FLOW FOR PRODUCTION OF DOUBLE LAYER PRINTED CIRCUIT BOARDS HOT AIR LEVELLED

MATERIALS USED	OPERATION	MACHINES/FACILITY
	FROM SHEET 1	
PLATING CHEMICALS	PLATE COPPER AND TIN – LEAD	AUTOMATIC PLANTING
	TAPE TEST FOR PEEL OFF	TERE STATION
	STRIP PHOTO RESIST FROM BLANKS	ADF STRIPPER
ETCHING CHEMICALS	ETCH AWAY UNWATED COPPER FOIL FROM BLANK	ALKALINE/ACID ETCH SYSTEM
	STRIP TIN – LEAD COMPLETE BLANK	TIN STRIPPER
	INSPECT WITH ATEO	ATEO
	COLD PLATE CONTACT AREA	AUTO. MICROPROCESSOR CONTROLLED PLATING
BLOCK OXIDE	BLACK OXIDE COPPER AREA OF BLANK	DO
SOLDER RESIST	APPLY SOLDER RESIST MASK	SCREEN PRINTER
	UV CURE MASK	U V CURING MACHINE
SOLDER	PRE CLEAN AND HOT AIR LEVEL THE BLANK	HOT AIR LEVELLER
INK/PAINT	APPLY COMPONENT REFERENCE	SCREEN PRINTER
	PROFILE CIRCUIT OUT LINE (PUNCH)	PUNCH AND BEVEL
	INSPECT	ATEO
PACKING MATERIAL	PACK	PACKING STATION

Table 14.2

Raw Materials etc. required for production of
1,200 sq. meters of double sided through hole glass epoxy
Printed Ciruit Boards

Item		Qty. Reqd. Unit	Qty	Unit Cost US$	Total Cost US$ (000)
1.	Double sided glass epoxy copper laminate	sq. m.	1,250	27.00	33,750
2.	Dry film photoresist	sq. m.	1,250	12.00	15,000
3.	Electroless & electro-plating chemicals		lot	-	20,000
4.	Echant		lot	-	4,000
5.	Solder Mask		lot	-	4,000
6.	Drill bits & routers		lot	-	3,000
7.	Others		lot	-	8,000
	Total				87,750

The material costs work out to about US$ 73 per sq. meter which is rather high compared to internationally quoted price of finished product of about US$ 125 per sq. meter.

Table 14.3

Typical Plant & Machinery required for an annual Production of about 30,000 sq. meter of double sided through hole Printed Circuit Boards

Item		Qty. Unit	Reqd. Qty	Unit Cost US$	Total Cost US$ (000)
A:	Laboratory for testing raw materials		Lot		20
B:	Instruments for in process and final testing				
1.	Plating Thickness meter		1		8
2.	Through hole tester		1		9
3.	Nickel thickness tester		1		4
4.	Visual Inspection		1		6
	Total B				27
C:	Production Machinery				
1.	Shearing & fabrication				
	a) Plate shearing machine		1		1
	b) Circular saw		1		10
	c) Pin router		1		6
	d) Power press		1		2
2.	Drilling & routing				
	a) 2 Head CNC (large)		1		80
	b) 2 Head CNC (small)		1		75
	c) Single spindle		1		60
	d) Manual optical drill		1		12
	e) Stack pinning machine		1		9
3.	Deburring				
	Deburring machine		1		25
4.	Electroless automatic mp controlled plating line		1		175
5.	Imaging				
	a) Pumice cleaning		1		18
	b) Hot roll laminator		1		8
	c) Double sided exposure unit		1		8
	d) ADF developer		1		18
6.	Electroplating				
	a) Automatic mp controlled electrolytic plating line		1		175
7.	Stripping & Etching				
	a) ADF stripper		1		18
	b) Alkaline etching system		1		40
	c) Acidic etching		1		36

(continued)

Table 14.3 (Continued)
Typical Plant & Machinery required for an annual Production of about 30,000 sq. meter of double sided through hole Printed Circuit Boards

Item		Qty. Unit	Reqd. Qty	Unit Cost US$	Total Cost US$ (000)
C:	Machines continued				
8.	Surface treatment				
	a) Tin Stripping		1		15
	b) Hot air levelling		1		40
9.	Screen printing				
	a) Clamps (screen stretching)		1 set		0.5
	b) UV light source		1		5
	c) Screen printer		1		12
	d) UV curing machine		1		5
	e) Oven		1		0.5
10.	Miscellaneous				
	a) Roller dryer		2		8
	b) Punches, tools etc	set			4
	c) Jigs, fixtures etc	set			4
	Total C				870.3
D:	Total Plant & Machines (A to C)				917.3
E.	Infrastructure				
1.	Land Sq.m.		10000	5	50
2.	Building (sq.m.)		2000	160	320
3.	Electric system & standby				64
4.	Water supply				16
5.	Environmental control				50
	Total E				500
F:	Total investment (D+E)				1,417

Capital recovery for a life of 4 years @ 12 % cost of money
33 % of F per annum 472

Capital recovery per 1000 sq. m.
i.e about 16 US$ per sq. meter.

Chapter 15

Integrated circuits

15.1 Introduction

The analysis of components going into the switching systems carried out in chapter 4 indicated that integrated circuits contributed the maximum to the cost of components in the system, over 25%. For a normal mix of 200,000 lines capacity 4.4 million IC's of over 200 types are used in a typical system. The analysis in chapters 7 and 8 indicates that IC's play an equally important role in Transmission systems. Though called a compoent, an IC is in effect a susbsystem or functional block, performing a complete function in the system. The complexitities of IC's range from the equivalent of a few transistors and diodes to the equivalent of thousands of component parts and they perform functions which vary from simple logic gates to amplifiers to complex central processing units. The equivalent component parts are not made seperately but share with each other the same processing, being fabricated on the same piece of silicon crystal.

The development of IC's has revolutionised electronics, telecommunications and computers. It has made possible the modern digital systems, improved the reliability, and brought about tremendous economies in use of materials.

15.2 Fabrication of IC's

Basically IC's consist of a single crystal of silicon, on which, through the processes of diffusion, ion implantation, metallization, and epitaxial growth, a complex structure is fabricated with areas which can be functionally identified as diodes, transistors, resistors, field effect devices, capacitors and interconnection wires. Fabrication involves extensive use, at highly sophisticated level of diverse scientific processes from physical chemistry, solid state physics, optics, photography, and metallurgy. The result is a higly miniaturised production of entire subsystems on chips as small as 2mm by 2mm. A large number, upto 2000, of these are produced simultaneously on a single slice of pure silicon, known as wafer, about 100 mm to 150 mm diam. At some stages of the processing as many as 50 of such wafers are handled together, with a possible output of from 50,000 to 100,000 chips at a time

15.2.1 Production of masks

The production process of an IC starts with the production of a set of masks called tools in the industry, which in turn starts with the design of the circuit. The essential steps in the production of the masks and the nature of the masks is as follows:

1) Creation of a circuit design and schematic diagram indicating clearly various devices and their interconnection. This is nowadays carried out on a computer aided design facility and the final output is available on a tape.

2) The tape is then used at a mask production facility, to produce a large map, several sq. feet in size, defining accurately locations of various devices to be formed into the crystal. Each such device takes its own unique design and shape e.g.:

- multiple layers form transistors
- two layers form diodes
- other structures form field effect devices
- interconnection pads are formed by a layer of positive metal or polycrystalline silicon

3) The drawing is transferred onto a series of rubyliths. Rubylith is a very rigid, perfectly clear plastic carrying a surface of ruby red film which can be removed by a cutting process. Layers of the IC are defined as layers on the series of rubylith.

4) Through a series of photo-reduction this rubylith map is reduced from several sq. feet to a photographic pattern 10 to 20 times the actual size of the silicon crystal. A final photographic process reduces the pattern accurately to the actual size of the crystal.

5) Using a step and repeat photographic process, the map is reproduced many times. (as many as the number of chips on the wafer which may be upto 2000) on a slide equal in size to the silicon wafer.

6) The end product is a set of photo masks of chrome or conventional emulsion on glass. Each mask is used to produce one of the layers that form the IC on the silicon wafer.

This set is used as a master from which copies are taken photographically for use in fabrication process. The production of these masks is a highly sophisticated process and is generally entrusted to a few dedicated mask shops specialing in this work. The prices quoted for a set of masks, which may consist of anything from 10 to 20 depending on the nature of circuits, range between 50,000 to 100,000 US$.

15.2.2 Fabrication of chips

The actual fabrication of chips starts with silicon wafers of high purity of 100 to 150 mm diameter. The steps in fabrication are indicated in chart 15.1 and are briefly as follows:

1) The silicon wafer is cleaned and polished in a polishing machine.

2) A thin layer of silicon dioxide is formed on the surface of the wafer in a controlled process in a furnace in presence of pure oxygen.

3) A thin layer of photo-resist material is applied uniformly over the silicon oxide layer in a spinning machine.

4) An appropriate mask is accurately aligned with the wafer and photographically exposed in a machine known as 'aligner'.

5) The photo resist is now developed in the photolitho equipment.

6 An ectchant is now used to eliminate the silicon dioxide from the areas not defined by the above photolithographic process.

7) A chemical clean up follows which removes the photolithographic materials and leaves the basic silicon with a silicon dioxide pattern on its surface.

8) In a diffusion furnace. dopant gases are now diffused at high temperatures. into the silicon areas not protected by silicon dioxide. Alternatively an ion implanting machine is used for achieving the same objective.

9) After each diffusion. the process starts over again with reoxidation of the surface. application of photoresist. exposure using the next mask. developing. etching. clean up and next diffusion. As many cycles as the masks follow. the last being the metallization and window masks which are used to provide the connection pads and define the boudaries of each IC chip. Chart 15.1 shows the reiterative process with 6 basic masks. As already mentioned the actual number may vary from about 10 to 20.

Throughout the processing. continuous monitoring and control is undertaken. optically. chemically and electrically to maintain a high level of accuracy. For this purpose the masks have a few strategically located test patterns.

At the end of the process. wafers are ready with the necessary IC's. Before being passed on for assembly. each IC is tested 100% on the wafer. and any defective ones are inked over. This is done using a prober.

15.2.3 Assembly

Chart 15.2 gives simplified process flow chart for assembly of IC's in moulded plastic packages. The steps are:

1) Probe testing . if not already done.

2) Dicing and seperation of IC's. This is done in scribling and dicing saw. The IC's are sorted out to seperate the defective ones and those carrying the test patterns. Latter are sent for further tests & evaluation of the process.

3) Each chip is too small for handling. It is therefore mounted on a substrate by a die bonding process.

4) For external connection. aluminium microwires (1 mil i.e. 0.001 diameter) already connected to external leads in a frame. are bonded. either by the ultrasonic or thermal compression process. one on each connection pad.

5) The chip mounted on the substrate and carrying the external lead frame, is moulded into a plastic package, in a transfer moulding machine.

6) The external leads are now tinned to ensure high solderability.

7) The external lead frame is then cut away.

The chips are now ready. They are finally tested and packed for despatch.

15.2.4 Raw material requirements

Table 15.3 gives a skeleton list of raw materials with an overall approximate estimate of cost, for production of about 40 million IC's with an yield of about 80

15.2.5 Plant and mahinery required

Table 15.4 gives a skeleton list of plant and machinery required for an annual production of about 40 million IC's of mixed complexity. Price estimates are highly approximate and give only an idea about the order of investments involved.

15.3 Observation

The fabrication of the IC's is a higly sophisticated process. It requires substantial investments. For an annual production of 40 million IC's whose selling price will be of the order of 40 million US $, the investment may be of the order of about 50 million US$. At this level the plant may just about break even. A number of major manufacturers are turning out IC's in billions.

Annexed:

Chart 15.1	**Typical simplified flow chart for production of Integrated circuit wafers.**
Chart 15.2	**Typical simplified process flow chart for assembly of IC chips.**
Table 15.3	**A skeleton list of raw material requirement.**
Table 15.4	**A skeleton list of plant and machinery required for an annual production of 40 million IC's of mixed complexity**

CHART: 15.1

TYPICAL SIMPLIFIED PROCESS FLOW CHART FOR PRODUCTION OF INTEGRATED CIRCUIT WAFERS:

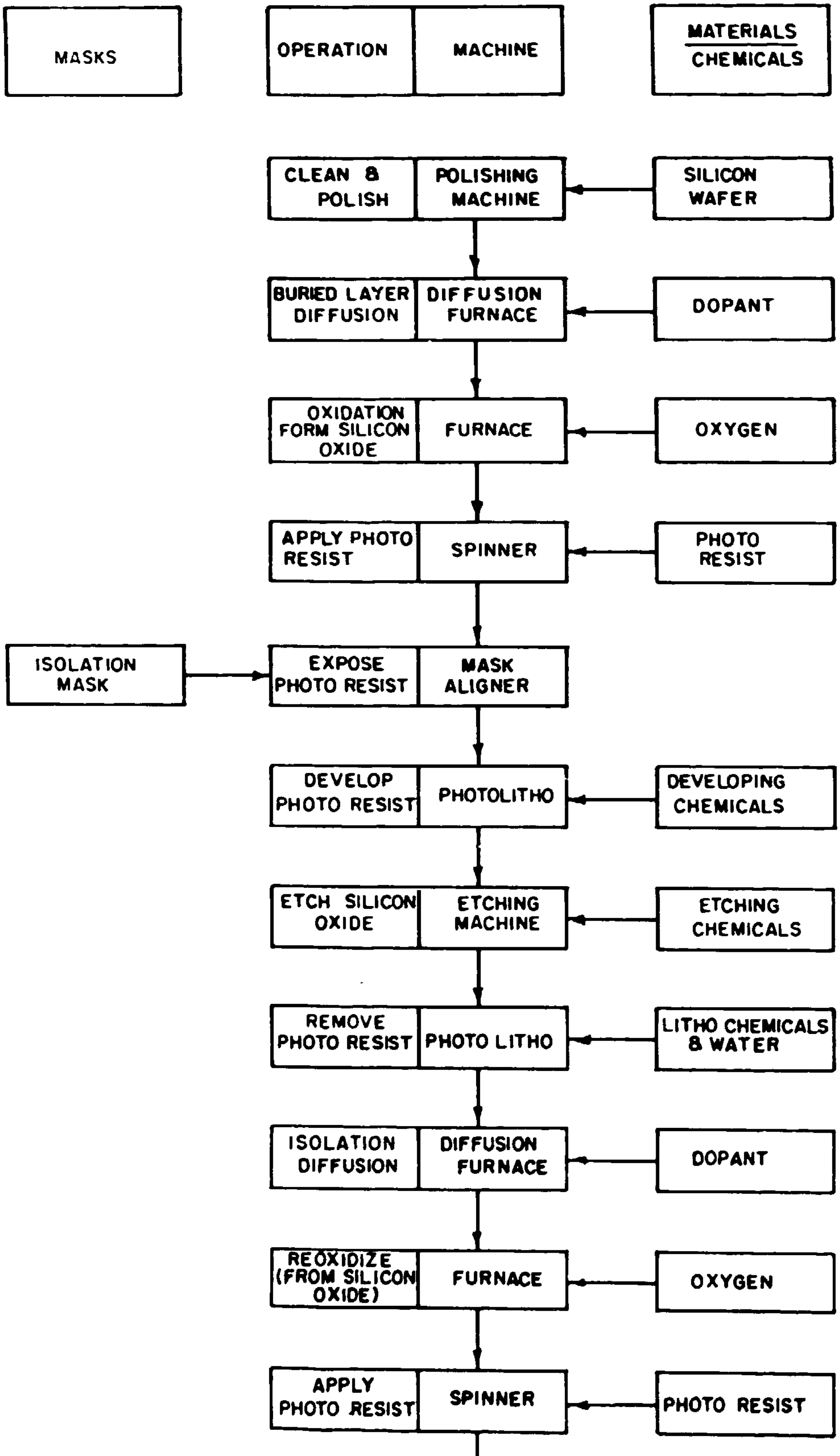


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CHART : 15.1 (CONTINUED)

TYPICAL SIMPLIFIED PROCESS FLOW CHART FOR PRODUCTION OF INTEGRATED CIRCUIT WAFERS.

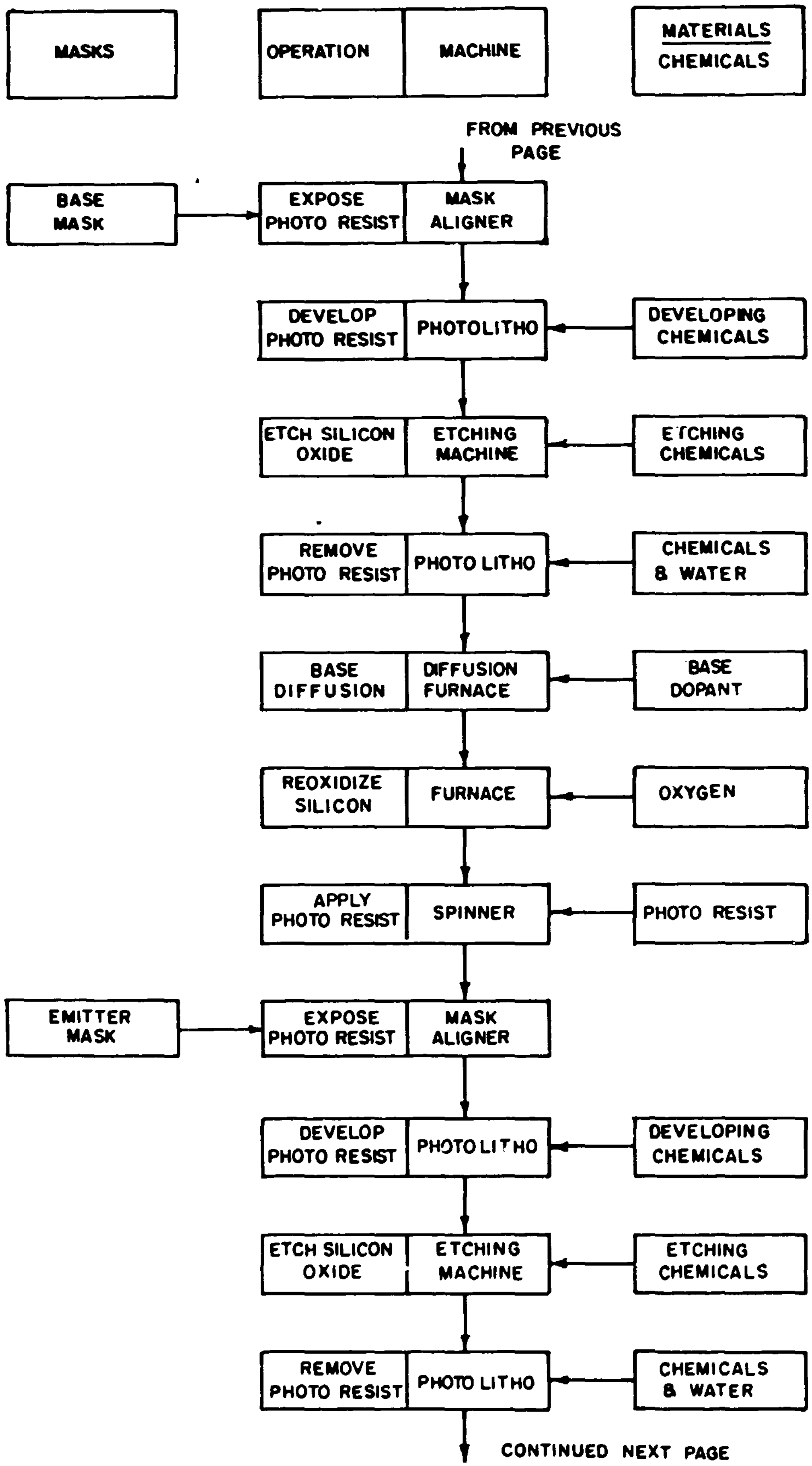

CHART: 15.1 (CONTINUED)

TYPICAL SIMPLIFIED PROCESS FLOW CHART FOR PRODUCTION OF INTEGRATED CIRCUIT WAFERS:

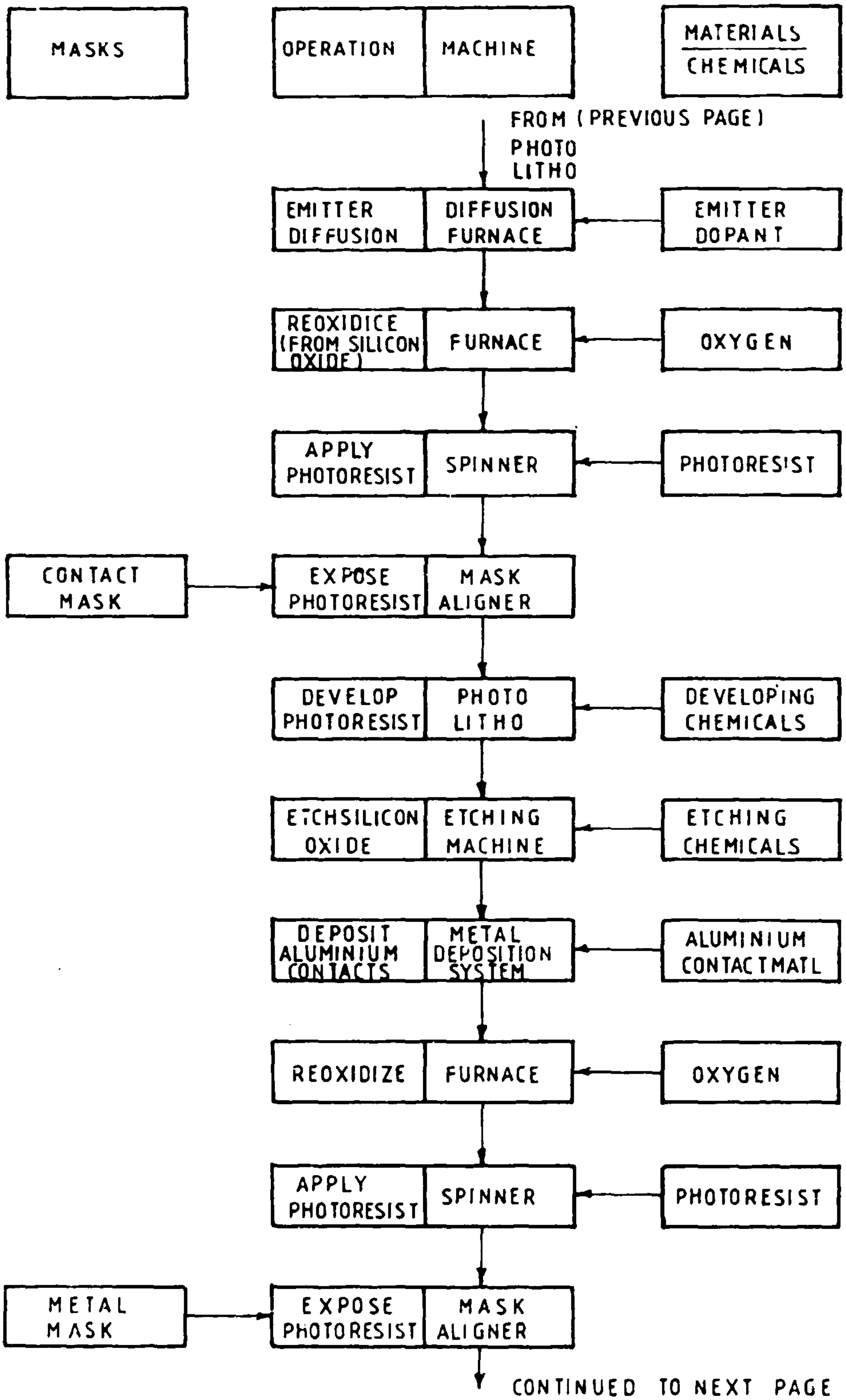

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CHART: 15.1 (CONTINUED)

TYPICAL SIMPLIFIED PROCESS FLOW CHART FOR PRODUCTION OF INTEGRATED CIRCUIT WAFERS:

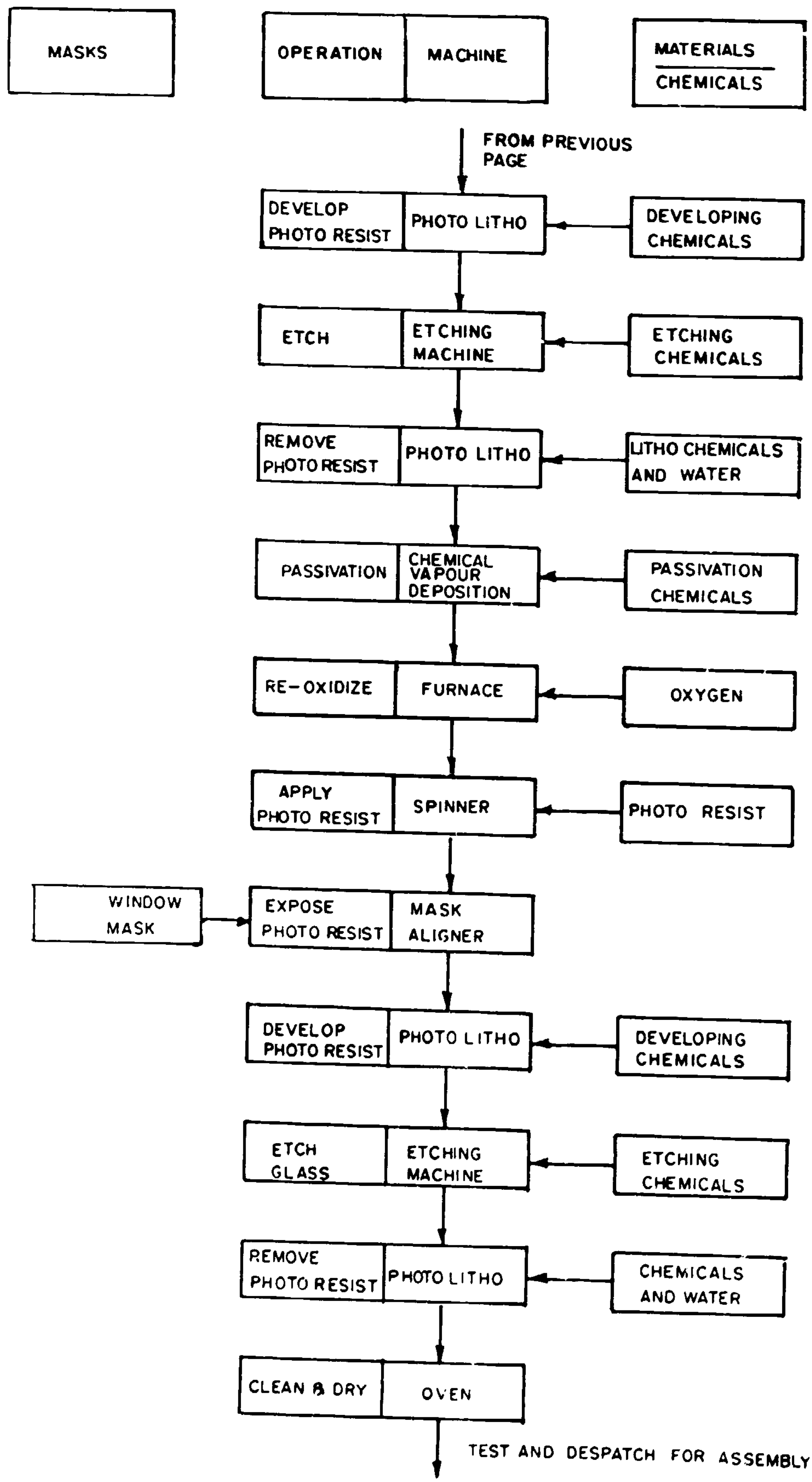

CHART: 15.2
TYPICAL SIMPLIFIED PROCESS FLOW CHART FOR ASSEMBLY/ PACKAGING OF INTEGRATED CIRCUITS.

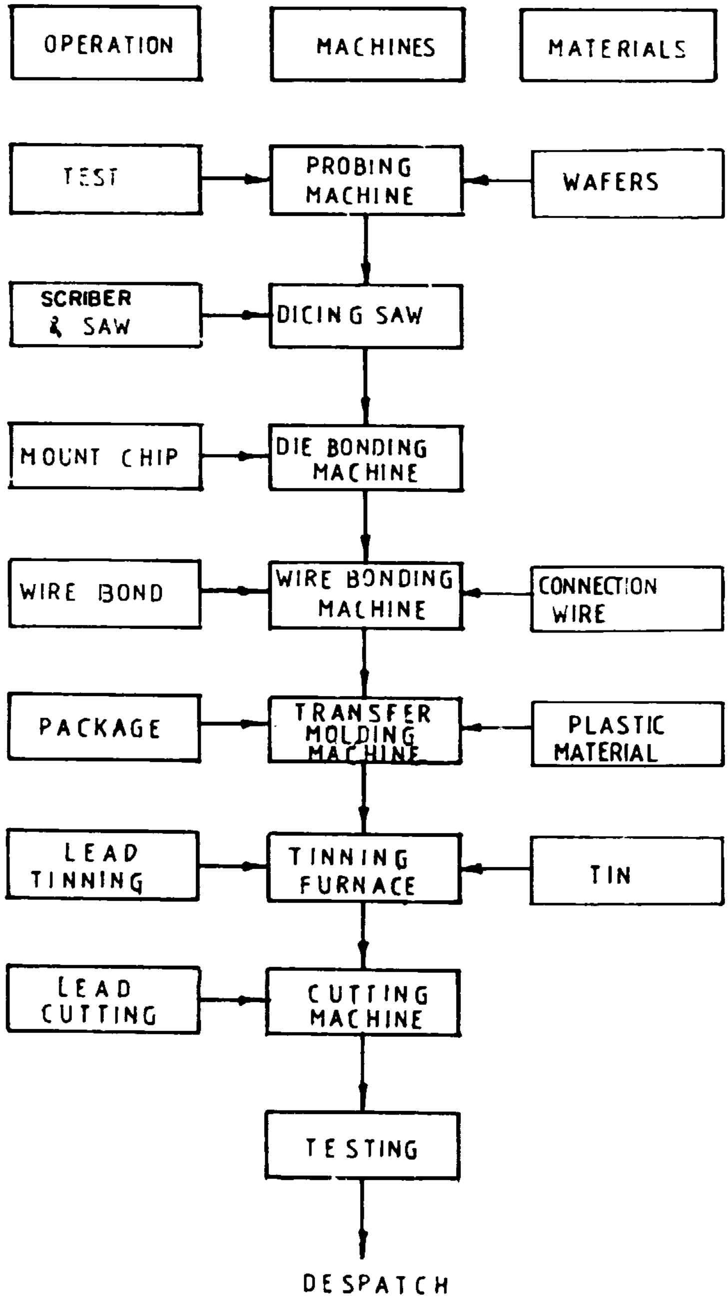

Table 15.3

A skeleton list of raw materials required for production of about 40 million IC's of mixed complexity

1.	Silicon Wafers		Approx cost US4
	100 mm diam	50,000	400,000
2.	Various chemicals	Lot	1,000,000

a) Cleaning agents
   Hydrochloric acid
   Hydrofluoric acid
   Sulphuric Acid
   Ammonium Hydroxide
b) Photo litho chemicals
c) Polymer
d) Dopants
   Arsene
   Phosphine etc
   Boron
   Gallium
e) Metallization chemicals
   Aluminium Silicon
   Aluminium Aluminium Copper
f) Vapour deposition
   Nitrous oxide
   Polysilicon
g) Oxygen

Table 15.4

Typical equipment requirements for an IC fabrication and assembly facility to produce about 40 million IC's of different complexities per annum

Sl no	Machine/equipment	No. reqd.	Unit Price US$ (000)	Total Cost US$ (000)
A:	Fabrication			
1.	Diffusion furnaces	32	27	853
2.	Ion Implantors	3	1,000	3,000
3.	Chemical vapour deposition system	12	167	2,000
4.	Metal deposition system	3	833	2,500
5.	Etch System, dry	4	333	1,333
6.	Etch system, wet	8	167	1,333
7.	Cleaning line	12	167	2,000
8.	Lithography			
	a) Mask aligner	8	167	1,333
	b) Wafer stepper	3	833	2,500
	c) Wafer track (photo-resist coat'g & devel'g)	6	200	1,200
	d) Oven	6	17	100
	Total A: fabrication			18,153
B:	In process control & monitoring			
9.	In-process control & monitoring	lot		3,333
10.	other Testing			10,000
	Wafer mapping	3		
	Resistivity			
	Thickness			
	Elipsometer			
	Device characteristics			
	Scanning electron microscope			
C:	Assembly			
10.	Wafer prober	1	167	167
11.	Assembly equipment lines each with:	6	1,667	10,000
	a) Dicing saw	3		
	b) Die bonding	2		
	c) wire bonding	2		
	d) Packaging			
	ceramic	1		
	plastic	1		
	e) lead cutting	3		
	f) lead tinning	3		
12.	Functional testing set up	1+1		1,000
	Total C: Assembly			11,167

Table 15.4 (continued)

Typical equipment requirements for an IC fabrication and assembly facility to produce about 40 million IC's of different complexities per annum

Sl no	Machine/equipment	No. reqd.	Unit Price US$ (000)	Total Cost US$ (000)
D:	Infrastructure			
1.	Land	125000		50
2.	Building			
	a) Clean area	4000	2	8,000
	b) Air conditioned	5000		2,000
	c) services	15000		2,400
3.	Power supply	Lot		3,200
4.	Pure gas supply			
5.	DI Water supply			
6.	Exhaust			
7.	Fire protection	Lot (4,5,6 & 7)		1,200
	Total D:			16,850

SUMMARY

A:	Fabrication	18,000
B:	In process control & monitoring	13,000
C:	Assembly	11,000
D:	Infrastructure	17,000
	Total	59,000

Chapter 16

Summary, observations & issues

16.1 Summary

16.1.1 In chapters 1 and 2 a quick survey has been undertaken of the structure of, and the major components systems that go into a national Public Switched Telephone Network, capable of supporting the plain old telephone, the facsimile, the low to moderate and even medium speed data and message transfer services. In Chapter 3 an analysis has been undertaken of the cost per line and major items that contribute to the cost. In chapters 4 through 10, a functional analysis has been made of a few typical systems, digital switching, a few digital transmission systems, a telephone set, and the jelly filled telephone and optical fibre cables, followed by an analysis of the raw materials, components , the processes and machines and plant involved in their production. In chapters 11 through 15 a similar survey of the components that go into the systems has been undertaken.

16.1.2 The survey indicates that the network essentially uses five broad categories of systems viz. the subscriber apparatus, the subscriber line network, the switching nodes, the transmission systems, and the operator services boards. The materials etc required for these constitute 80 to 85 % of the total cost of network. The engineering, and the construction and installation, which mostly consist of the manpower efforts, contribute the remaining 15 to 20% of the network cost. The actual costs and their distribution between different component systems varies (Tables 3.3 to 3.5) from an overall about 1000 US$ per line in high density areas to over 2500 US$ per line in low density areas with difficult terrain.

16.1.3 The overall network investment costs in developing countries have thus been substantial and have inhibited their effective growth commensurate with the infrastructural needs of the concerned countries. Given the important role the telecommunication services play in overall economic development there is need to reduce these costs and promote development of the national networks.

16.1.4 There can be considerable uniformity in the technology and products throughout the network in respect of the switching systems, the operator services boards, the subscriber apparatus and the subscriber line network. However the choice of transmission systems in different parts of the network will vary significantly according to the traffic and terrain.

16.1.5 Reduction in network costs calls for a number of strategies at various levels:

- Reduction in procurement costs through better competition among suppliers.

- Optimisation of network engineering

- Taking advantage of low manpower cost in developing countries, both for network engineering and construction and for production of systems and components

16.1.6 Some of the systems and products are simple, easy to produce, and are used in large quantities e.g. telephone sets, jelly filled telephone cables, and certain hardware used in subscriber line networks. Some of the other systems are complex and call for substantial investments for production. Even in these, certain modules are simple, comparatively easy to produce and are needed in large numbers e.g. subscriber line module in switching systems.

16.1.7 Among the components, some are used in very large numbers, an average of 1 to 12 or more per line, while others are used only in small numbers. Among those used in large numbers some are comparatively simple to produce e.g. resistors, capacitors and coils, others are extremely complex to produce e.g. I.C.'s and transistors. Processes vary very widely, some involve simple mechanical operations like plastic moulding, metal forming etc. Others involve highly complex chemical. metallurgical, and photographic processes.

16.1.8 Construction practices and processes for assembly line production of electronic systems including telecommunication systems, have been fairly standardised. So are the plant and machinery required for this work. The investment required for basic assembly operations is also moderate. However the systems involve detailed testing at the board and integration levels. The test instruments, and the test set ups vary very significantly and are comparatively highly costlier.

16.1.9 There are around 10 major multi-national corporations which produce almost the entire range of telecommunications systems generally of their own design and many of the more important components. There are however a significant number of others who produce various ranges of equipment and components. There are a number of major independent manufacturers of components. A number of developing countries have manufacturing industries of their own, producing some systems and components under licence from the multi national corporations and a few of their own design.

16.1.10 Because of the many independent manufactures of components, there is a reasonable competition and many components are available internationally at competitive prices.

16.2 Observations and issues

All through the survey the basic objective of the conference to discover opportunities for economy and reduction in cost in building up and expanding the networks in developing countries through mutual cooperation by way of coordination in procurement and industry was kept in view. On the basis of this survey following observations are made and issues brought out for further examination and consideration by the conference.

1) A variety of systems go to build up the national networks. There are trade offs possible between them to achieve maximum economy in the overall investment. Careful design by way of number and location of subscriber and transit exchanges. the traffic routing. choice of systems etc. can contribute significantly to the overall economy.

2) Manpower costs in developing countries are significantly less than those in developed countries, by a factor of 10 or more. Substantial manpower costs are involved in the design, engineering and construction of national networks, and production of systems and components. Maximizing the use of local manpower, and that from sister developing nations could lead to significant economies. What strategies could be adopted towards this objective?

3) There are large material input costs in the network, by way of switching, transmission, subscriber line, subscriber station and other equipment. In many developing countries these have to be entirely imported, largely from developed countries. The costs depend to a very large extent on the level of competition between the suppliers a country is able to generate. The competition depends somewhat on:

- the magnitude of order or the size of the market.
- the terms of payment
- competence of the local engineers in drawing up the specification and evaluation of offers

In general, smaller developing countries are handicapped on all these counts. Cooperation in procurement could possibly increase competition by way of increase in the size of market and of pooling the technical and finacial expertise. How far is this feasible? What strategies could be adopted to promote this?

4) The alternative of local or regional manufacture of systems and components can be considered. The major cost elements in manufacture are:

- Cost of raw materials and components
- Capital recovery costs on investment in plant and machinery
- Manpower costs
- Infrastructural costs, power, water, communications etc
- System and process knowhow fees

a) The brief analysis of a few typical systems indicates that the raw materials and components are available internationally at competitive prices, in particular where these are not controlled by the manufacturers of systems or components themselves.

b) The capital recovery costs depend on the cost of capital goods. The capital goods appear to be available internationally at competitive prices.

c) In developed countries manpower costs appear to account for about 20 to 25% of the total cost of production. With their comparatively lower manpower costs. developing countries have a natural edge. What strategies could be adopted to take advantage of this edge?

d) In respect of infrastructure. developing countries are somewhat at a disadvantage. However a number of them have demonstrated that with a will they could build it up to support the modern industry at least on a selective basis.

e) The issue of system and process knowhow is however an imponderable one. Excluding this element of cost the developing countries appear to be in a position to effect significant economies by local or regional manufacture on a cooperative basis. In the short term there is no alternative but to negotiate with the manufacturers in developed countries. One needs to deliberate whether regional cooperation could help in securing better terms in such negotiations.

f) In the long term. the surest way to get around this problem is to develop own competence and knowhow. Again one needs to deliberate whether regional cooperation could be effective in the development of systems. devices and process knowhow and if so what form it should take and how it should be institutionalised.

5) Quite apart from the benefit of reduced costs for own network. the analysis of the production requirements of both the systems and the components. seems to point to an opportunity. for the developing countries offering their services. for such manufacture in developing countries to the traditional multinational manufacturers. Some countries in East Asia have already taken advatage of this.

6) The analysis of manufacturing processes and plants for the systems shows that the modern technology has significantly simplified and standardized the assembly of systems from components. The investments in purely assembly line production seem to be quite small. There are however very significant costs in regard to testing set ups. Firstly the cost of some test instruments appears to be large. and secondly there seem to be substantial costs involved in proprietary software of automatic test set ups. Developing countries could contribute by reducing these costs by developing their own software for such test set ups.

7) The analysis of manufacture of systems and components clearly shows that with capital equipment and raw materials and components procured at international prices. the local manufacture could result in production at significant savings compared to the prevailing international prices even after paying for the system and process knowhow. However the experience in some countries has been that local production costs have been significantly higher. Could some of the following factors be responsible for this?

- Significant taxes on import of both the capital goods and the raw materials and components

- Employment of much larger number of operatives and support hands than needed, treating the industry as a soft option to generate employment

- Complicated procedures and delays in regard to procurement from abroad of raw materials and components leading to failure of the 'just in time' procurement and delivery systems and economies flowing from them.

- Much higher costs of borrowings

Any proposals for regional cooperation in industry will perhaps need to address these issues.

8) With a back up for assured and timely supplies of component kits, the assembly level production of a number of systems appears to be simple and cost effective even at moderate levels of production. Could this possibly become the nucleus of regional cooperation in production of components and kitting for local manufacturte of systems in participating countries?

9) There have been useful achievements in regard to development of systems of special application to developing nations in some of the developing countries. How can other developing nations take advantage of the same? How could there be a freer exchange of information and pooling of knowhow for mutual advantage?

10) Many of the countries in the region have been procuring systems and equipment through international or limited international competitive bids. It is well known that different countries are paying significantly different prices. However there is very little authentic information available. Could there be a suitable data base for exchange of information not only on prices but also the performance of various systems? Will there be any legal problems in this regard? Could this become the beginning towards closer cooperation in procurement?

11) The analysis in regard to requirement of components and their manufacturing processes indicates that there is fairly large demand for some components and possibilities exist for their economic production in some of the developing countries. Could a bank of skeleton project reports help entrepreuners in the countries in the region to evaluate the same for taking them up? Could a regional data base help?

12) A number of systems and components are being produced in some of the developing countries of the region. While international directories of components and products being produced in developed countries are fairly readily available, same is not true for production in the developing countries within the region. Could a regional data bank help?

13) The quality and reliability of components and systems in a network is of paramount importance. In local or regional production quality has to be maintained. Could there be some regional cooperation in regard to ensuring the quality of products produced within the region and also to share the information and experiences in this regard?

14) Any joint procurement action presupposes common standards and specifications and an agreement to use the same systems. Is it feasible? How can it be achieved?