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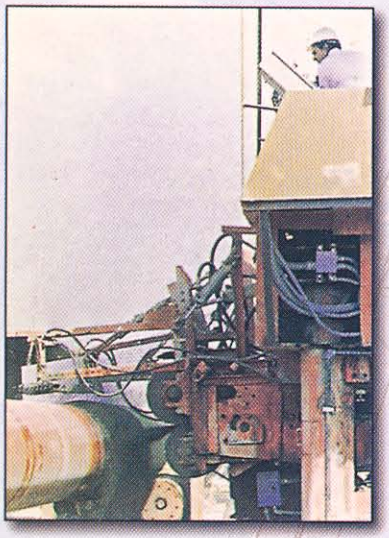

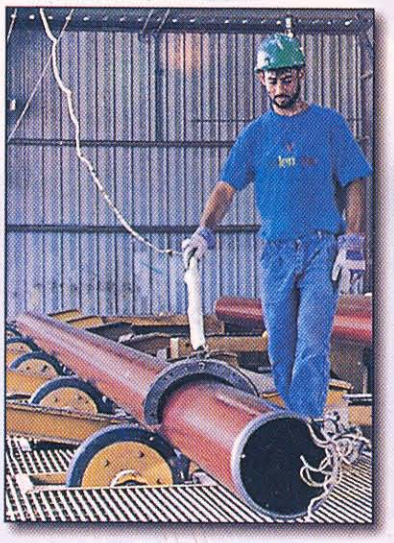

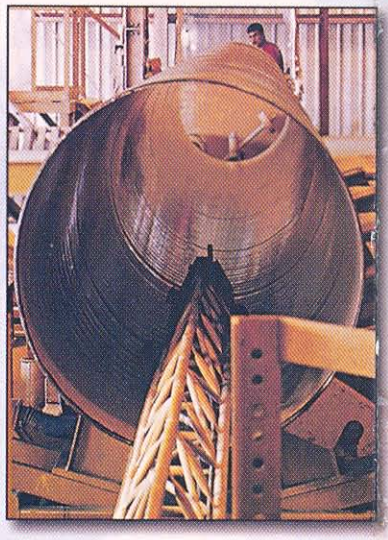

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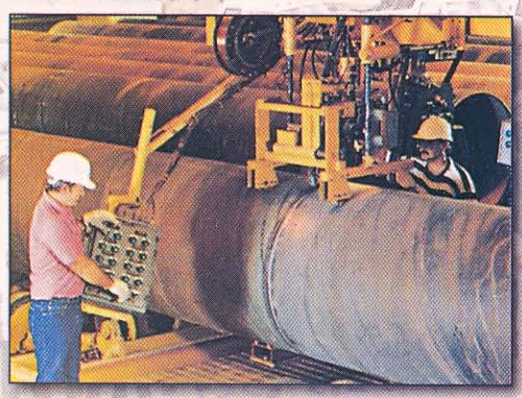

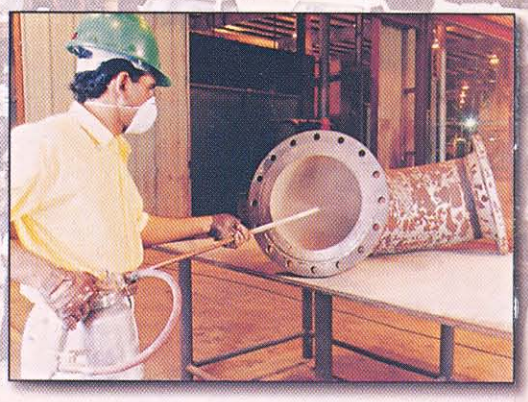

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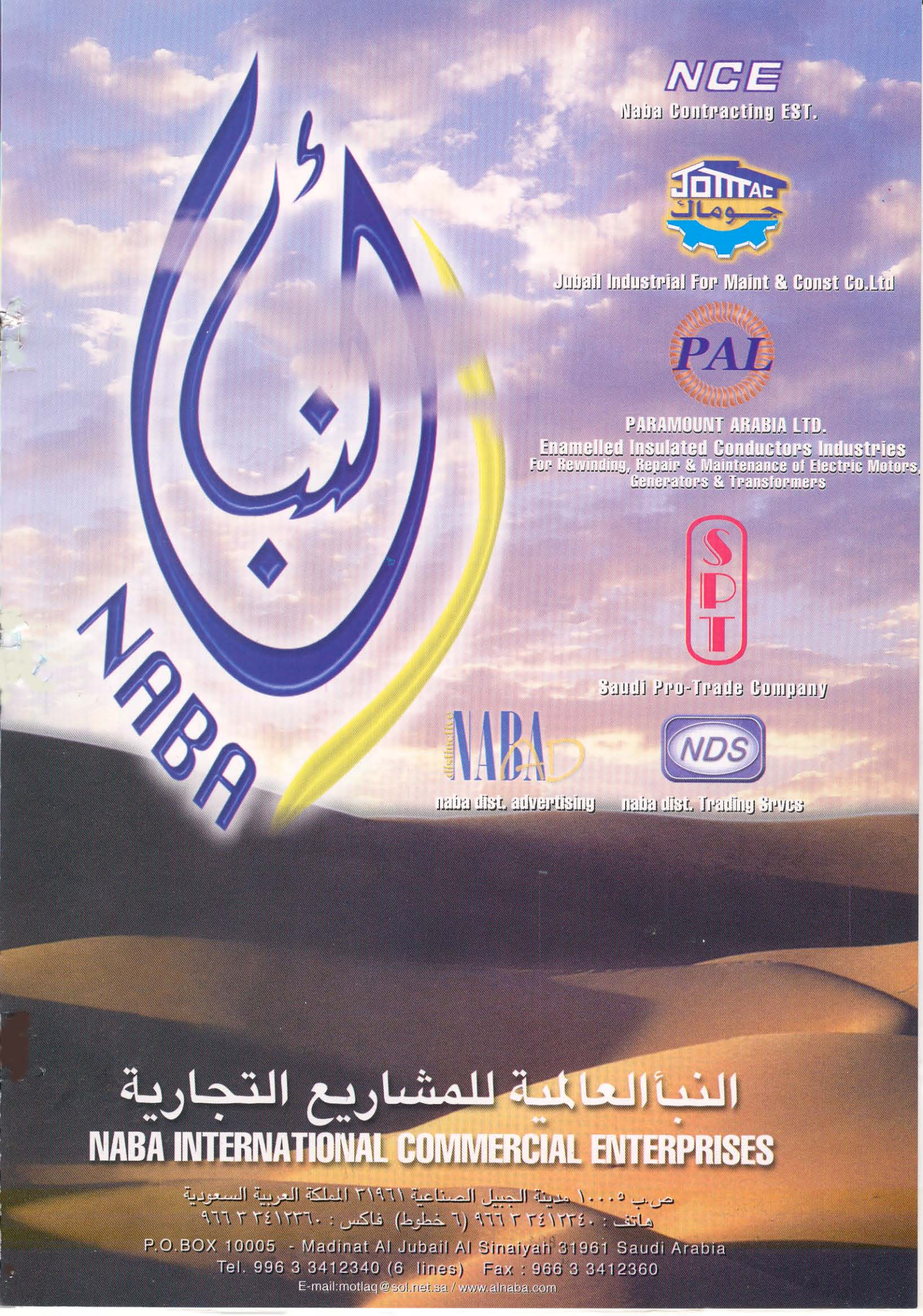
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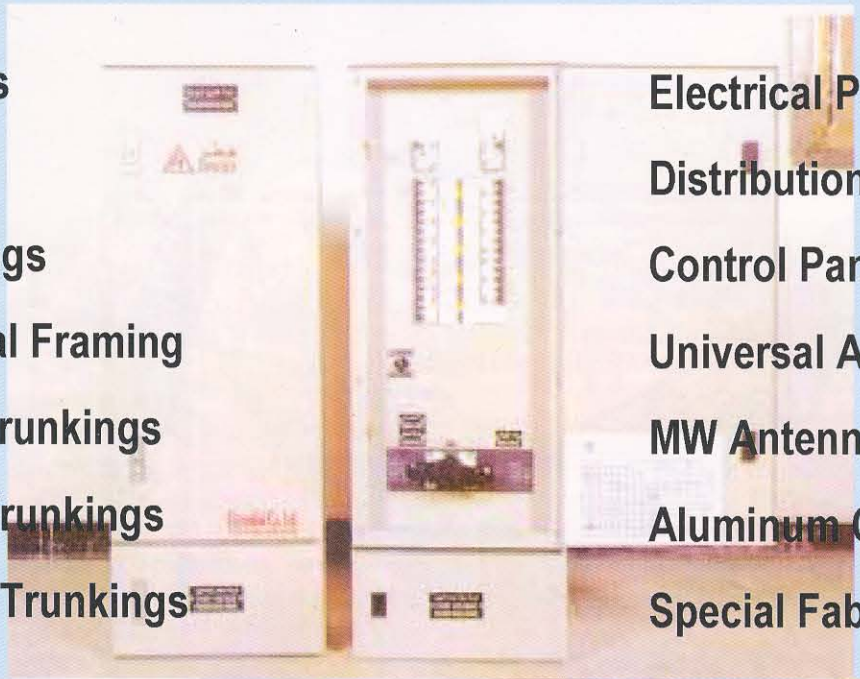

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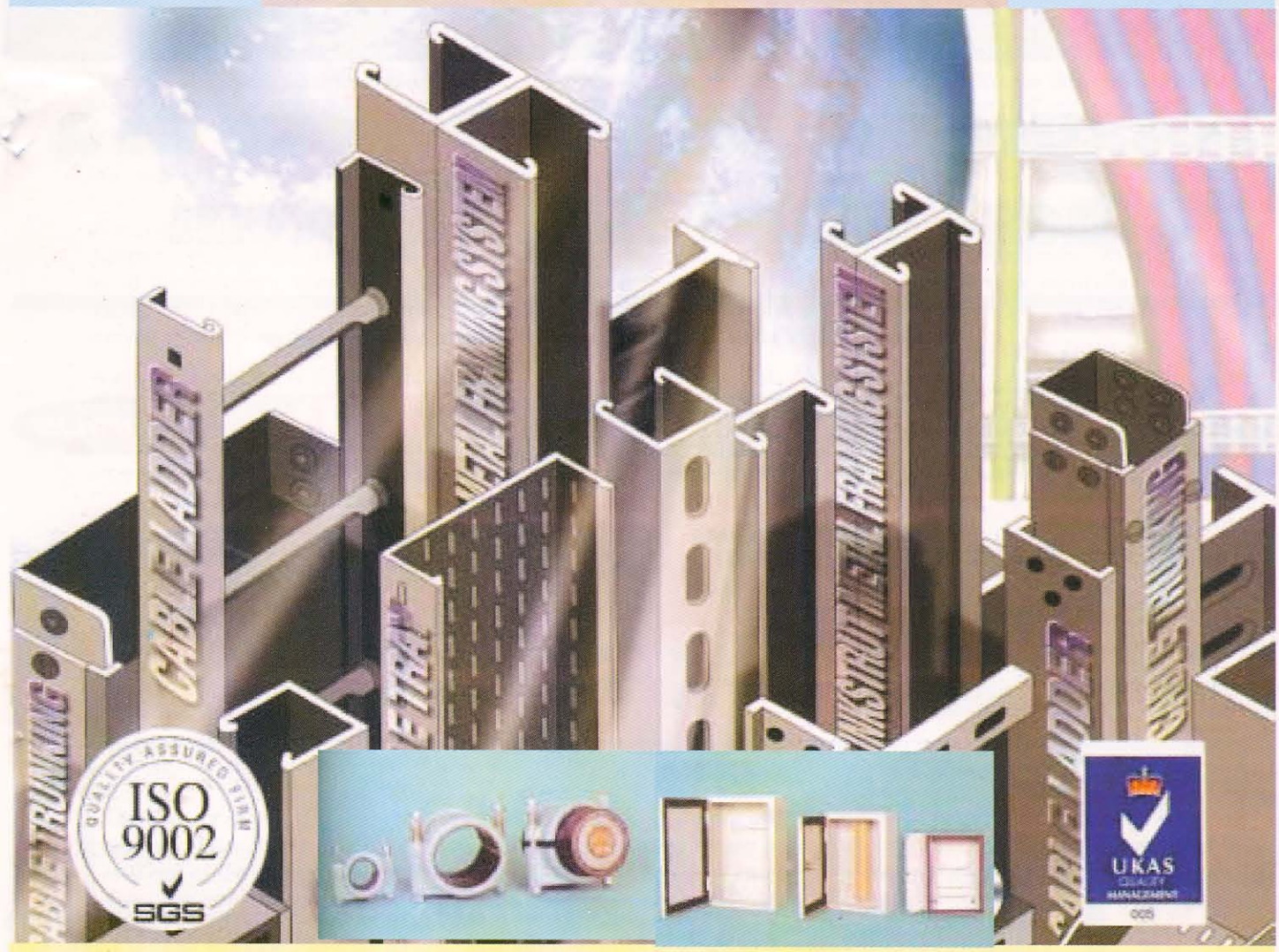

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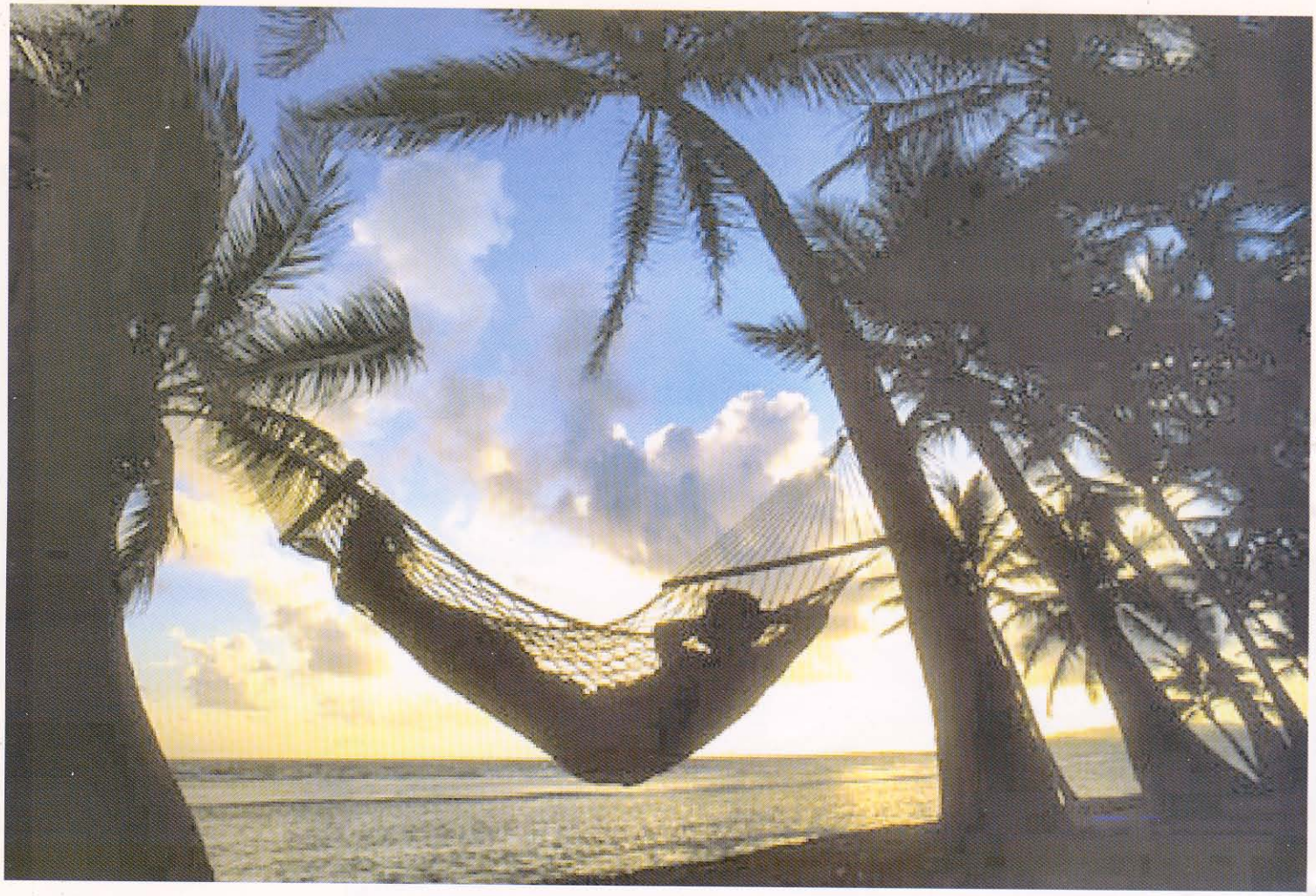

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FOREWORD

The Institution of Engineers Pakistan, Saudi Arabian Center (IEP-SAC), is pleased to present the IEP- Journal for the year 2004-2005. It contains a number of technical papers authored by our members as well as an up-dated directory of the Pakistani Engineers in the Kingdom of Saudi Arabia. The main objectives of the IEP-SAC are to provide avenues and means of updating professional knowledge of Pakistani Engineers in the Kingdom of Saudi Arabia and to facilitate effective communication among them.

We as Pakistani Engineers have an excellent opportunity to further enhance our technical and managerial imagine by excelling in our assigned jobs / projects by means of presentations and / or technical papers in the international magazines and / or conferences as well as ensuring TRANSFER OF TECHNOLOGY TO OUR SAUDI COLLEAGUES. The Pakistani Engineers working in the Kingdom enjoy two important distinctions. Firstly, they are involved and associated with one of the largest development programs in the World history which provides an opportunity to be exposed to a multitude of modern technologies and its challenges. Secondly, they constitute the highest number of Pakistani Engineers in any single country outside Pakistan. Therefore, we have additional obligations to uphold the expectations and demands of these distinctions.

I am very pleased to announce that WAPDA has extended the deputation period from 5 years to 10 years for their engineers. This extension was achieved due to the continuous efforts of the IEP-SAC by writing and discussing with the Minister of Power, Chairman and member power of WAPDA. At this occasion, I would like to thank the Chairman, Member power of WAPDA and the Ambassador of Pakistan in Saudi Arabia for their support and understanding of this important issue.

We wish to express our deep appreciation for the voluntary but extremely valuable efforts of the members of the Local Council of IEP-SAC, and other friends of IEP-SAC in collecting the information and processing it against a very tight deadline. We are pleased to thank the IEP-HQ Pakistan for their continuous support. We wish to thank the Sponsors and Advertisers also who extended their support to make the publication of the Journal possible. Furthermore, We are thankful to all the engineers, town planners, architects and allied professionals who have submitted their particulars for the up dating of the directory. In addition, We are also thankful to our speakers and authors who have taken a considerable amount of time from their very busy schedule to prepare the presentations and technical papers.

We are grateful to H.E. the Ambassador of the Islamic Republic of Pakistan and his embassy staff for their usual cooperation and support.

We also take this opportunity to thank the Government of the Kingdom of Saudi Arabia for their hospitality and cooperation to the Pakistani Community in the Kingdom in general and Pakistani Engineers in particular.

Engr. Syed Mohammad Jaleel Hasan
Chairman
Institution of Engineers Pakistan
Saudi Arabian Centre

16th December 2004
04th Dhul Qaadah 1425H

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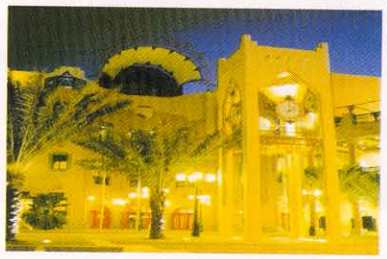

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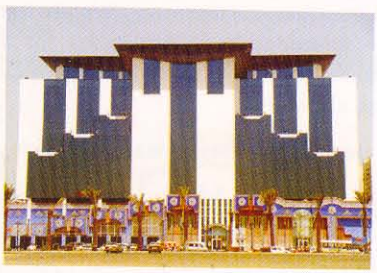

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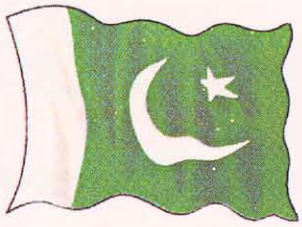

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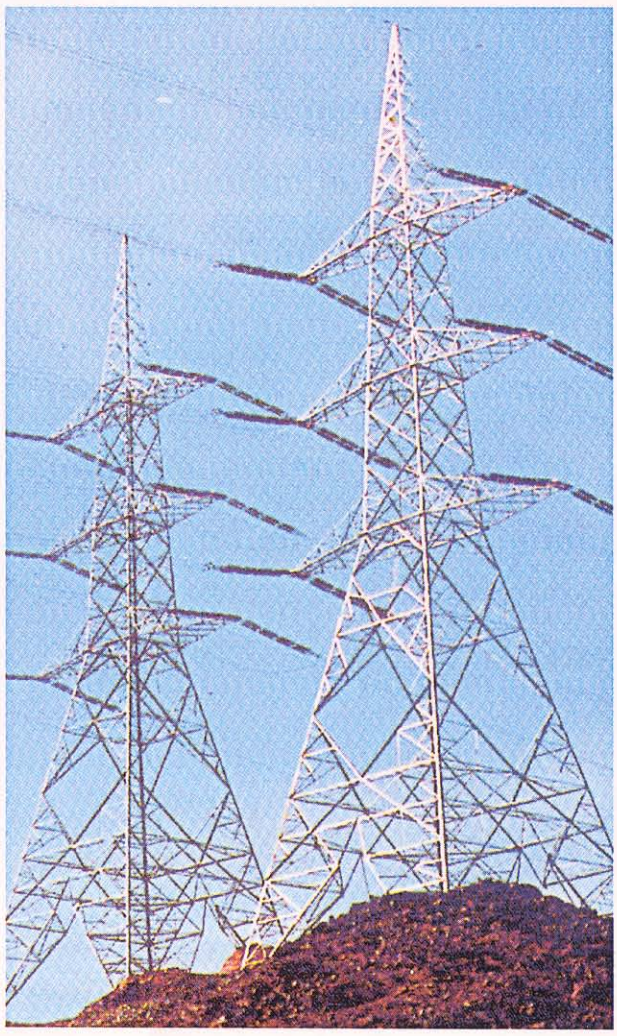

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Message of Admiral (Retd) Abdul Aziz Mirza, Ambassador of Islamic Republic of Pakistan to the Kingdom of Saudi Arabia

I wish to congratulate the Institution of Engineers Pakistan – Saudi Arabian Centre (IEP-SAC) for organizing a Seminar on topics of "Technology Park" and "The Challenges of a Mega Project". The technology is advancing at a rapid pace and the dissemination of such information is timely.

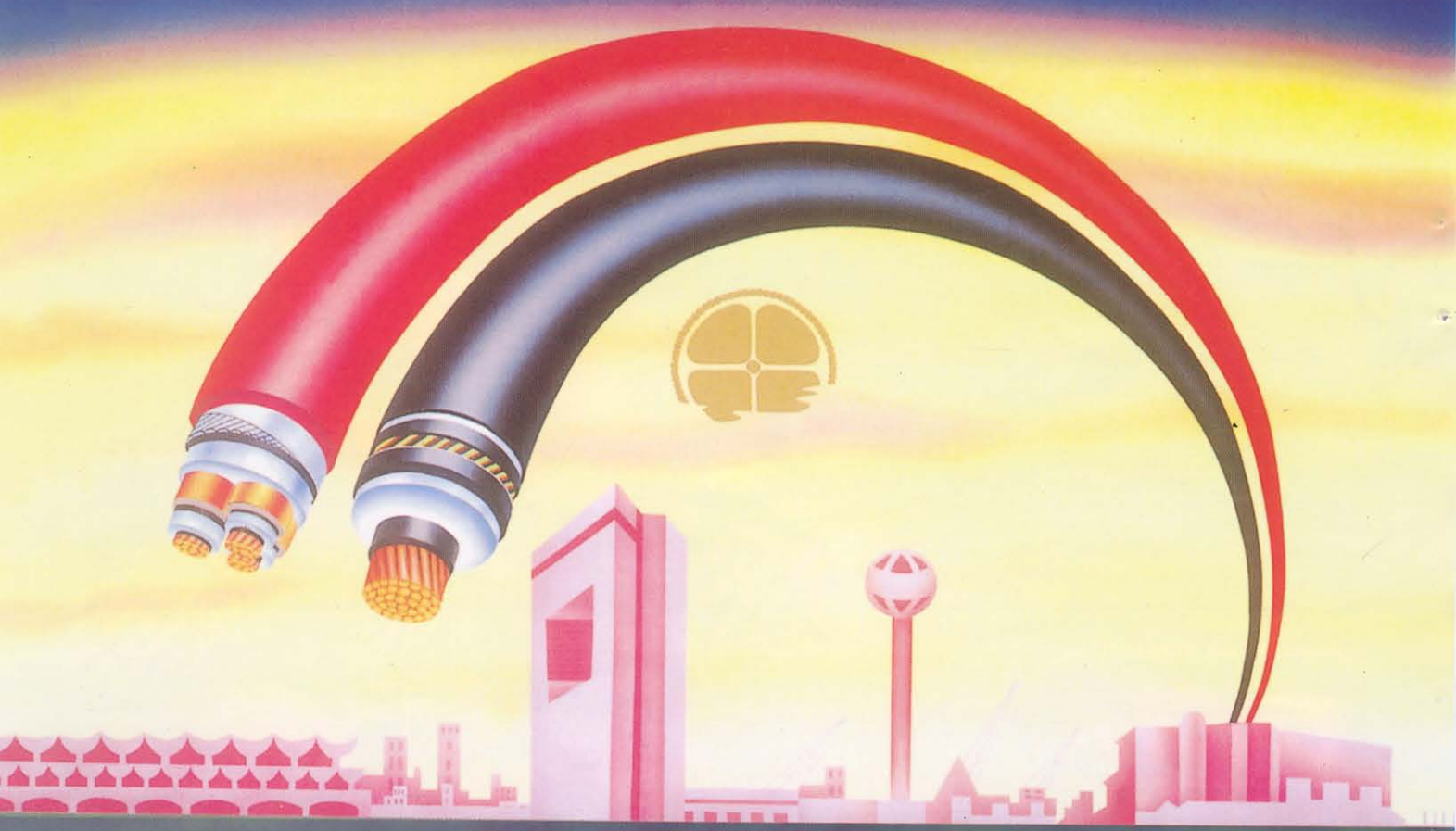
The idea of Technology Park is getting popular and several such centers are being built in developed countries. The Mega Project Challenges are also unique and a discussion of such challenges would certainly be very informative.

As the Ambassador to the Kingdom of Saudi Arabia, I am pleases to learn that IEP-SAC has distinguished itself as a vibrant forum for Pakistani Engineers, Architects & Town Planners, who have earned good name for their motherland by their sheer hard work, dedication and professional skills in the development of brotherly Kingdom of Saudi Arabia. By holding seminars on various professional topics from time to time, IEP-SAC provides its members opportunity to share experience and knowledge with each other on a variety of subjects.

I call upon all the distinguished engineering professionals in the Kingdom to keep up their good work with full devotion and commitment. I wish to assure them of the Embassy of Pakistan's continued support in the pursuit of their professional activities and noble endeavours.

Finally, may I also take this opportunity to congratulate the Institute of Engineers Pakistan – Saudi Arabian Center for publishing an update of the directory of Pakistani Engineers in Saudi Arabia along with a number of articles of professional interests. I hope that the Directory will not only be a useful source of information for the members of IEP-SAC but will also prove equally beneficial to other interested organizations and to serve as a strong bondage for the country.

Admiral (Retd) Abdul Aziz Mirza
Ambassador of the Islamic Republic of Pakistan



مواجهة التحديات ومواكبة التغيرات

منتجاتنا على الدوام متوافقة للأداء في أصعب الظروف

منتجات الشركة:

١- كابلات الضغط المتوسط والعالي.

* كابلات ثلاثية الأوجه معزولة ومسلحة وغير مسلحة حتى جهد ٢٢٠ ك.ف.
* كابلات أحادية الوجه - معزول المادة XLPE حتى جهد ٢٢٠ ك.ف.

٢- كابلات الضغط المنخفض:

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* كابلات أحادية الوجه ذات موصل مصمت أو مجدول من النحاس ومعزولة بمادة الـ P.V.C
* كابلات أحادية الوجه ذات موصلات مرنة ومعزولة بمادة الـ P.V.C
* كابلات متعددة الأوجه ذات موصلات نحاسية مرنة معزولة ومغلفة بمادة الـ P.V.C
* كابلات متعددة الأوجه ومفلطحة ذات موصلات نحاسية مصمتة مجدولة معزولة مغلفة بمادة الـ P.V.C
* كابلات ضغط منخفض للتمديدات الداخلية.

٣- كابلات ضد الحريق وقليلة الأدخنة غير محتوية على الهالوجين وذلك للإستخدامات الخاصة.

٤- كابلات دعامية هوائية.

٥- موصلات هوائية.

* موصلات نحاسية قاسية ومعزولة بمادة الـ P.V.C

٦- كابلات للتمديدات الداخلية.

٧- كابلات التحكم.

٨- كابلات اخرى متخصصة.

٩- مركبات عديد كلوريد الفينيل P.V.C صالحة للإستخدام في صناعة الكابلات الكهربائية - الأحذية - الليات - الليات المرنة - الليات القاسية - الأنابيب - الوصلات - العبوات البلاستيكية - مواد ملونة.

١٠- قضبان النحاس ٨ مم.

١١- البكرات الخشبية والبلاستيكية.

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AL-TUWAIRQI GROUP

Chairman's *Message*

It is with great pride and pleasure to inform you about the tremendous growth and success of Al-Tuwairqi Group. From the establishment of Al-Ittafaq Steel Products Factory (ISPF) in 1989, it was a simple and hand run unit producing merely 1000 tons per month of quality hot rolled steel sections. In a period of 15 years, due to implementation of new and advanced technologies, ISPF has increased its production capacity to 1.250 million tons. This excellent growth, a world record, was achieved through the hard work and dedication of all the team members of Al- Tuwairqi Group.

During this period, we have moved to integrated steel plants. We are committed to our valued clients and customers to provide our best quality products and services, which would bring more profitable benefits for them and to us in the years to come.

I strongly believe that team work, vision, joint efforts, collective ideas, concerted strengths and discipline are the important requisites of our successful business.

Dr. HILAL H. TUWAIRQI

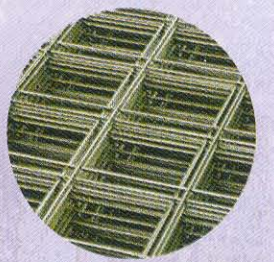
Company *Profile*

Al -Tuwairqi Group of companies is one of the leading business concerns in the Kingdom of Saudi Arabia. From a humble beginning in 1977, the growth in the last two decades and in the year 1999, made its entry into the top hundred companies in KSA on turnover basis and among the top fifty Saudi companies in terms of the profitability index. With its portfolio of diversified business activities, the Group has gone beyond the boundaries of Saudi Arabia into other areas of Middle East as well. Beside trading and contracting activities, the Group is also engaged in distribution of building and materials, white cement, and trading of industrial materials throughout the kingdom of Saudi Arabia. Al -Tuwairqi Group is extensively engaged in manufacturing various types of products including Steel Billets, Hot Rolled Steel products, reinforced wire mesh, Galvanized Steel , fusion bonded epoxy coated Steel and electrical equipment.

OUR *vision*

Al- Tuwairqi Group is an ISO 9001:2000 and CARES certified company for its production facilities. The Group is a responsible corporate citizen with ethical practices and environment friendly waste disposal methodologies.

It provides a stimulating working environment to attract and retain professionals who are committed to their work and achievements. Dedicated to extend services and reach technical excellence, the Group envisages a vision that continues its core strength and provides the basis for a growing number of satisfied customers.



OUR *Mission*

The management of Al-Tuwairqi Group is enthusiastic for continual improvement of its management quality systems in accordance with the requirement of ISO 9001-2001, CARES and also committed for

- Creating, stimulating and rewarding the work environment.
- Identifying, setting and achieving the quality objectives at relevant functions by providing adequate resources, training and development human resources.
- Providing quality products and services.
- Meeting mutual contractual obligations.
- Ensuring customers satisfaction and enhancing productivity and efficiency.
- Achieving business leadership by devotion.
- Reviewing quality policy periodically.
- Producing quality products according to the international standard.
- Maximum production of iron, steel and electrical products for our clients.
- To provide on timely delivery.
- To maintain efficient customer's services at all times.
- To sustain effective and consideration support to client.

AL-ITTEFAQ STEEL PRODUCTS FACTORY

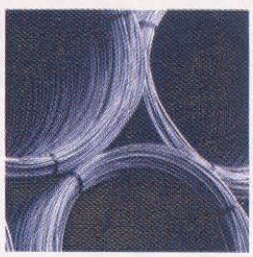
COMPANY *PROFILE*

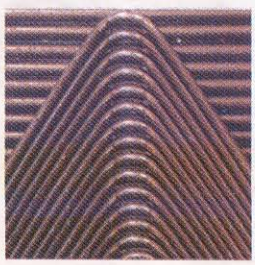
Al Ittefaq Steel Products Factory is one of Al- Tuwairqi Group of factories. ISPF is considered as a premier & one of the biggest of its kind in the Kingdom and Middle East in the private sector producing hot rolled, high tensile. Weldable reinforcement steel bars of sizes from 5.5mm to 40mm, manufactured by using the
Thermax Bar Quenching process, conformed to the international standard such as
ISPF is achieving a production of 1.250.000 metric tons per annum.
ISPF has secured its leadership position through its commitment to quality & innovative management thereby forging its policies to meet the future challenges confidently. Since 1998 onward & through an amalgam of targeted Investment; the company has adopted a focused & proactive management, meticulous quality control system from raw material to finished goods, with a world class in-house material testing laboratory.

PRODUCTS

ISPF produces high tensile steel bars known as
1- Deformed reinforcement Bars according to ASTM A615Grade 60, Grade 60/40,BS -4449, Grade -460/250,SASO SS A2-1992
Diameter Range: 8,10,12,14,16,18,20,22,25,28.32 and 40mm
Bar Length: 6 Meter and 12 Meters
Bundles: Approx.2,000 Kg-Except 8mm with 1,000 Kg
Annual Production Capacity: 900,000 Tons
2- Wire Rods, generally used to make spring wire, tying wire, nails, wire mesh, galvanized wire etc.
Diameter Range: 5.5mm to 14mm (plain) and 8.0 to 16mm (deformed)
Coil Weight: Approx. 1800 Kg.
Annual Production Capacity: 350,000 Tons

AL-FASAIL STEEL PRODUCTS FACTORY





As Kingdom of Saudi Arabia's economic development emerges strongly, the steel industry has been enhancing & influencing the Kingdom's economic policy& contributing its might in this direction. In this course Al- Tuwairqi Group of companies has emerged as a giant entity. From this entity Al-Faisal Steel Products Factory (FSPF) was born. It is one of the largest downstream steel units in the Middle East under one roof, providing value added steel products

PRODUCTS

Wire Mesh, Galvanized Steel, Cut and Bend Steel Rebar, Spring Wire,Fusion Bonded Epoxy Coated Steel

MAJOR PROJECTS

Due to the big efforts made by our mother company ISPF which is the biggest Hot Rolled high tensile steel mill, we are on the approved list of

Sabic
Saudi Aramco
Sceco
Gasco
Royal commission
Ministry of education

Some of successful projects
King Faisal University
Sceco project
Al Dabal Tower
Al Subaie Tower
Al yammama project

NATIONAL STEEL & IRON FACTORY





COMPANY *PROFILE*

NSIF is a state of the art steel plant producing the steel billets with the option to double the present capacity of 500,000 ton through EAF, LRF & CCM route.

Main facility of the plant includes

Electric Arc Furnace (EAF) of 80 ton capacity.
Ladle Refining Furnace (LRF) of 80 ton.
4 strands continuous Casting Machine.
Scrap storage & management system.
Dust collecting system (DCS) for Environmental & pollution control to collect the dust generated during steel making
Utilities
Substation & SVC system.
Store & ware house.
Central Maintenance shop.

PRODUCTS:

Finished product is billet or bloom. Billets or blooms are sold square or rectangle shape with specific content of iron,carbon,manganese,silicon,chromium,niclel,molybdenum,sulfur,phosphorous etc,as per standard,
Different grades of low carbon steel, medium carbon steel or low alloy steel can be produced.

THAMESTEEL LIMITED





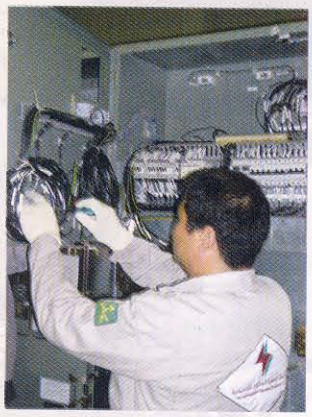
COMPANY *PROFILE*

Thamesteel is based in the southeast of the England in the estuary of the River Thames approximately 80 km form London. Steel making commenced on the current site in 1972.
The Al-Tuwairqi Group purchased the site and production facilities in January 2003 and formed Thamesteel which then commenced production on March 10, 2003.
Thamesteel manufacturers continuous cast billets at the rate of 740,000 tons per annum and the majority of the production is currently shipped to the kingdom of Saudi Arabia for conversion into reinforcing products at AL ITTEFAQ STEEL.

PRODUCTION

The raw material for the steel production is ferrous scrap which is delivered by road and by rail to the site and method I a UHP electric arc furnace with a pre- heating shaft. The steel is reined in one of two secondary steel making units before being continuously cast into high quality 150mm square sections in 6.1 and 9.5 lengths. Before transferring to the docks for shipment the billets are packed into 10 tons units for ease of handling. The packs are assembled into 50,000 tons lots for loading on to vessels in sheerness docks, located just 0.5 km from the works. A direct transfer to Dammam takes approximately 21 days.
In preparation for the build up of tonnage at NSIF which will supply rolling in Dammam, Thamesteel has started to develop more local outlets for the sale of its billets though development is at an early stage. During 2005 a bar rolling mill will be installed on the Thamesteel site and the production from this unit will gradually build to approximately 500.000 tons per annum by which time the Saudi factories will be more self sufficient to feed stock for their mills.

THE INTERNATIONAL ELECTRICAL PRODUCTS COMPANY



Electrical Division of Al Tuwairqi Group is one of the pioneers in the switchgear industry in the kingdom of Saudi Arabia.

It started its manufacturing activities in 1987 for the Medium and low voltage switchgears. In 1998 the premises was upgraded to build a new and modern factory with the name 'The International Electrical Products Est (TIEPCO).

Within short span of time since inception of its modern plant TIEPCO is now enjoying status of approved manufacturer for Saudi Electricity Company for numerous products like Metered CB Ring Main units, package substations and Relay control Panels. For Saudi Aramco TIEPCO is the approved manufacturer of relay and control panels. For government ministries and departments and for the industrial and building sector TIEPCO is also supplying value added metal Clad switchgear under partnership agreement with world renowned manufacturer Alstom (Areva)

TIEPCO has recently launched its Automation wing in order to further explore business in the manufacturing if automation panels and intelligent motor control centers. Further more TIEPCO is providing systems integration services through this wing.

Other Divisions of Al-Tuwairqi Group

The Scientific and Medical Division (SMD) is comparatively a younger member of Al-Tuwairqi group. Born in 1998, SMD ,thru direct marketing channel is serving Health Care and medical research units by offering quality products and after sales services for
Leica microsystem,compound+Stereo+Surgical+Scanning Microscope, LEO Electron Microscope,Forensic Science Equipment,medical kits. Etc

Industrial Supply Division (ISD),thru its extensive network of dealers is serving the local industries by offering top quality industrial consumables like working and welding gloves, Neoplene rubber sheets welding rods, V-belts, safety shoes tie wires ,Solid MIG and flux core wires etc.

IT Division is providing seamless integration of the Group by customized MIS and implementation of SAP. Finance and cost ,material management. sales and distribution, quality management modules have already successfully been implemented.

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- Chilled Water & Duct Fabrication
- Steel Structure & Gantry Towers
- Transformer Steel Gratings & Bird Screens
- Transformer Sunshade Roof
- Water & Fuel Storage Tanks Fabrication
- Fabrication of Cyclones for cement plants

Adding Value & Innovation

alfa fabrication works supports regional activities by providing specialist skills in the areas of high quality structural steel fabrication, piping fabrication, HVAC ductwork, plate work and associated services, for Power Plant and Substations.

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alfa has continually been competitive nationally in providing its clients with quality fabricated products.

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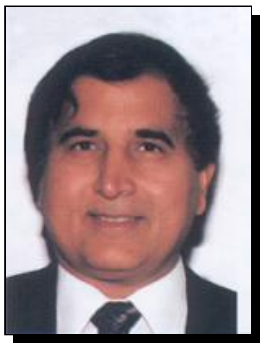

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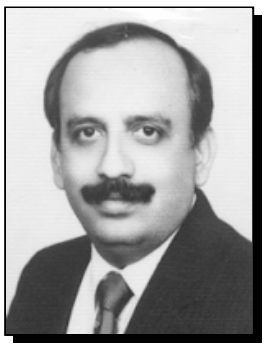

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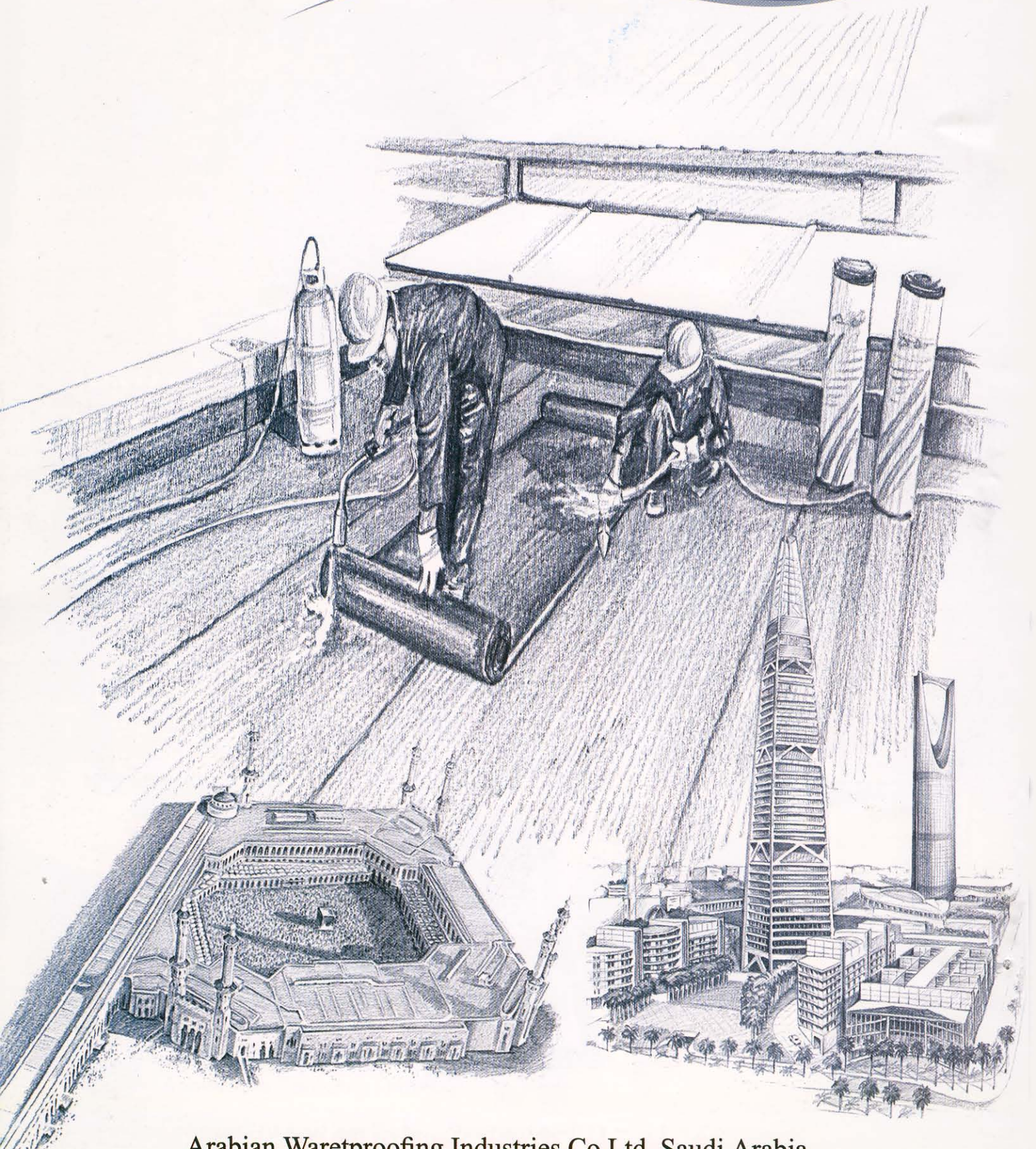

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GLIMPSES OF IEP-SAC ACTIVITIES

(Right): The chief guest, Admiral (Retd) Abdul Aziz Mirza, Ambassador of Pakistan to Saudi Arabia, is delivering a speech on the occasion of a seminar on "*Desalination: Past, Present and Future*", held on 23rd October 2003.

(Center): The speaker, Engr. Fayyaz Muddassir Mubeen, Desalination Expert at SWCC Jubail, is giving his presentation during the seminar.

(Left): Engr. Dr. Nazar Malik, Convenor Seminar Committee, is introducing the Speaker.

An impressive view of a section of audience of the seminar on "*Desalination: Past, Present and Future*" held on 23rd October 2003 at Prince Salman Social Center, Riyadh.

Admiral (Retd) Abdul Aziz Mirza, Ambassador of Pakistan to Saudi Arabia, and Engr. Jaleel Hasan, Chairman IEP-SAC, is visiting one of the exhibitors stand at the occasion of a seminar on "*Desalination: Past, Present and Future*".

GLIMPSES OF IEP-SAC ACTIVITIES

Admiral (Retd) Abdul Aziz Mirza, Ambassador of Pakistan to Saudi Arabia, is presenting a memento to the keynote speaker, Engr. Fayyaz Muddassir Mubeen, Desalination Expert at SWCC Jubail, on the occasion of a seminar on "*Desalination: Past, Present and Future*". Standing beside him is Engr. Jaleel Hasan, Chairman IEP-SAC.

A group photo of some of the IEP-SAC Local Council members with the Ambassador and the Speaker on the occasion of the Seminar on "*Desalination: Past, Present and Future*", held on 23rd October 2003.

A group photo of some of the IEP-SAC Local Council members with the Speaker on the occasion of the Seminar on "*Karachi Mass Transit Project*" held on 24th March 2004.

GLIMPSES OF IEP-SAC ACTIVITIES

(Right): The chief guest, Admiral (Retd) Abdul Aziz Mirza, Ambassador of Pakistan to Saudi Arabia, is delivering a speech on the occasion of a technical seminar on "*Karachi Mass Transit Project*", held on 24th March 2004.

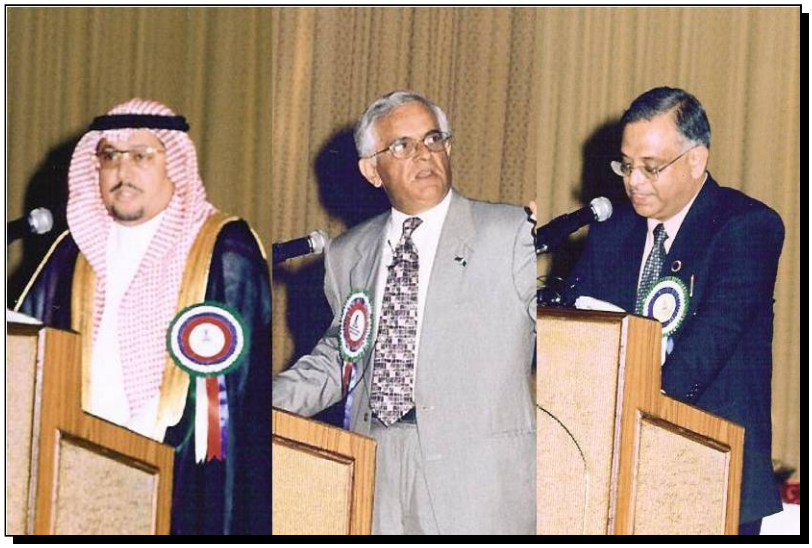
(Center): The speaker, Engr. Karamat Ullah Chaudhary, Vice President Naespak Pakistan, is giving his presentation during the seminar.

(Left): Engr. Jaleel Hasan, Chairman IEP-SAC, is saying thanks to the Chief Guest and the Speaker.

A view of a section of audience of the seminar on "*Karachi Mass Transit Project*" held on 24th March 2004 at Minhal Holiday Inn Hotel, Riyadh.

Admiral (Retd) Abdul Aziz Mirza, Ambassador of Pakistan to Saudi Arabia, is presenting a memento to the keynote speaker, Engr. Karamat Ullah Chaudhary, Vice President Naespak Pakistan, on the occasion of a seminar on "*Karachi Mass Transit Project*". Standing beside him are Engr. Jaleel Hasan, Chairman IEP-SAC, Engr. Dr. Nazar Malik, Convenor Seminar Committee, and Engr. Masood Khan, General Secretary IEP-SAC.

GLIMPSES OF IEP-SAC ACTIVITIES



(Left): The chief guest, Sheikh Tariq Abdel Hadi Al-Qahtani, Chairman A.H.Abdullah Al-Qahtani Group of Companies, is delivering a speech on the occasion of a seminar on "*Karachi Mass Transit Project*", held on 25th March 2004.

(Center): The speaker, Engr. Karamat Ullah Chaudhary is giving his presentation during the seminar.

(Right): Engr. Rizwan Ahmed is presenting a report on IEP-SAC (EP) activities.

An impressive view of a section of audience of a seminar on "*Karachi Mass Transit Project*" held on 25th March 2004 at Dhahran International Hotel, Dhahran.

Sheikh Tariq Abdel Hadi Al-Qahtani, Chairman A.H.Abdullah Al-Qahtani Group of Companies, is presenting a memento to the keynote speaker, Engr. Karamat Ullah Chaudhary, Vice President Naespak, on the occasion of a seminar on "*Karachi Mass Transit Project*".

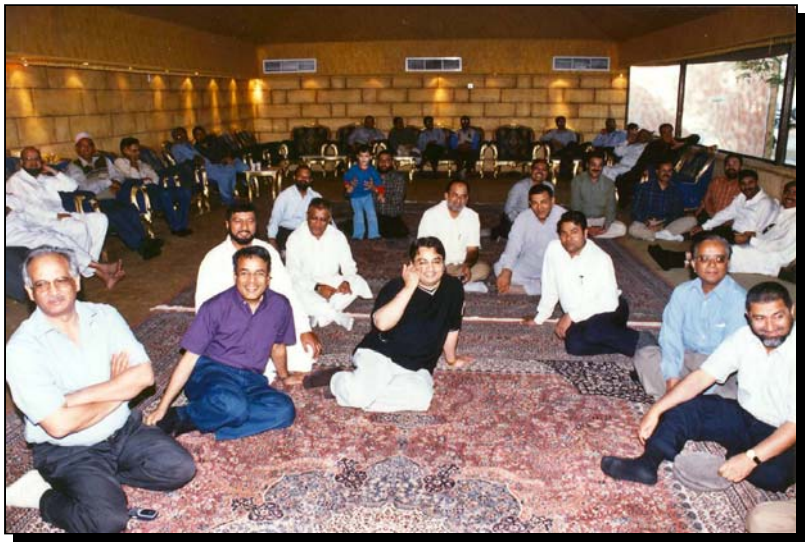
GLIMPSES OF IEP-SAC ACTIVITIES

A group photo of IEP-SAC (Eastern Province) Local Council members with the Chief Guest and the Speaker on the occasion of the Seminar on "*Karachi Mass Transit Project*" held on 25th March 2004.

Engr. Jaleel Hassan, Chairman IEP-SAC, and Engr.Ismat Amin Khawaja, Chairman IEP-SAC (EP), are presenting a Fellow Member certificate to Engr. Rizwan Ahmed on 25th March 2004.

A group photo taken at the occasion of a fairwell party held in honour of IEP-SAC Local Council Member Engr. Syed Azhar Maqsood on 15th September 2004. Sitting from left to right are Engr. Obaidullah Siddiqi, Engr, Tanwir Qamar, Engr. Syed Azhar Maqsood, Engr. Masood Khan, Engr. Nazar Malik and Engr. Jaleel Hasan. Standing from left to right are Engr. Khalil Ahmed, a future Engineer, Engr. Arshad Jamal, Engr. Shaikh Asrar Ahmed, Engr. Waheed Mir, Engr. Saifullah Saleem and Engr. Naveed Ahmed.

GLIMPSES OF IEP-SAC ACTIVITIES



Engineers are participating in a "*Bait Bazi*" competition on the occasion of a "*Family Picnic*" held on 27th February 2004.

Engineers are participating in a "*Musical Chair*" competition on the occasion of a "*Family Picnic*".

Engr. Jaleel Hasan, Chairman IEP-SAC, is giving prizes to the winners of the *Games* and the *Bait Bazi* competition. Other prominent figures in the picture are Engr. Masood Khan, Engr. Saifullah Saleem, Engr. Shaikh Asrar Ahmed and Engr. Khalil Ahmed.

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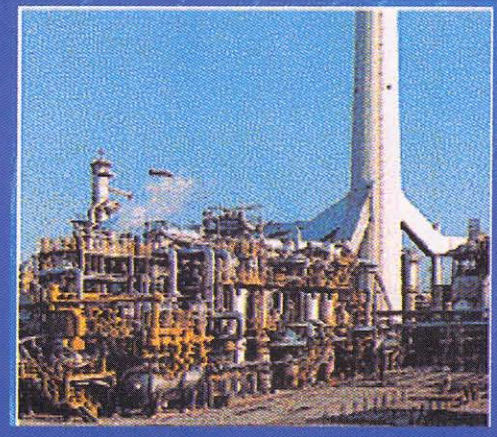

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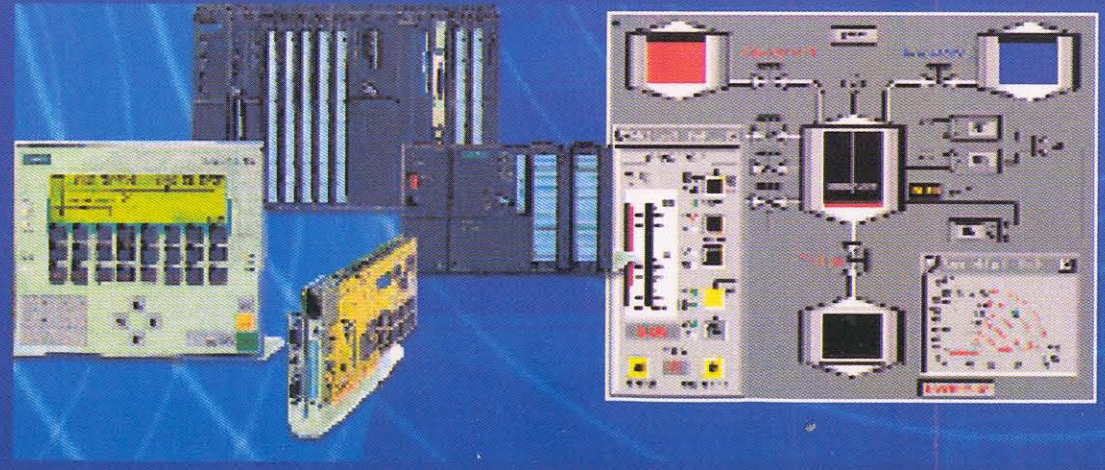

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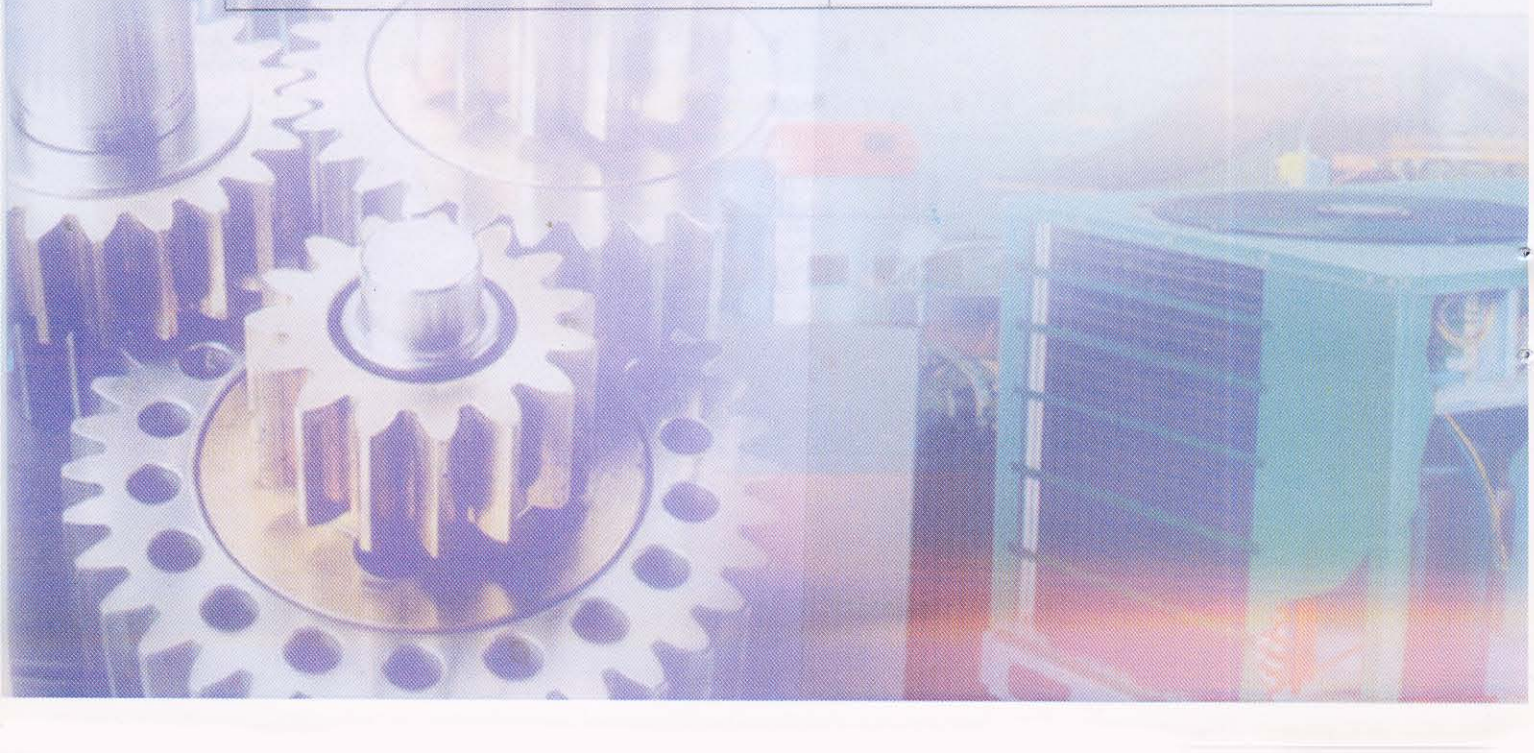

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GENERAL SECRETARY'S ANNUAL REPORT

I have the pleasure to present the annual report of IEP-SAC on the activities and events that took place during the year 2003-2004.

IEP-SAC has been actively pursuing its objective of creating a community spirit and fellowship among Pakistani Engineers working in Saudi Arabia. In addition, IEP-SAC strives for disseminating and sharing of latest technical knowledge among engineers. IEP-SAC also runs an ambitions scholarships program for deserving Pakistani engineering students.

IEP-SAC have continued to pursue its above stated objectives in this reporting period with full enthusiasm. A brief of the activities since January, 2003 is given below:

IEP-SAC organized its annual Seminar and Dinner on 23 October 2003. Engr. Fayyaz Mudassir Mubin (Desalination Expert) from Saline Water Conversion Corporation (SWCC) Jubail – Saudi Arabia was the keynote speaker. The topic of the Seminar was "*Desalination Past, Present & Future*". The function was presided by H.E. Ambassador of Pakistan. On this occasion IEP-SAC had published its annual Journal including the directory of Pakistani engineers residing in the Kingdom of Saudi Arabia.

The great annual social event of IEP-SAC is the family picnic which was organized on 27 February 2004. Family picnics are very successful events attended by over 150 families each time in a rest house at the outskirts of Riyadh. Family picnics provide opportunities for cementing ties among engineering community in a relaxing and entertaining environment.

A Technical Seminar was organized and conducted on 28 March, 2004. This year's Technical Seminar topic was "*Karachi Mass Transit Project*". The presentation was given by Engr. Karamatullah vice president NESPAK. The Seminar proved to be very interesting and was well received by engineering community in Riyadh.

IEP-SAC has increased its Scholarships awards to 85 this year to provide financial assistance to the needy and deserving Engineering students in Pakistan. The recipients are selected from 11 Engineering Universities / Colleges spread all over Pakistan and Azad Kashmir.

I appreciate the dedication of our Council members in making all of the above events a great success. I also appreciate the support and guidance of IEP head quarter and the full support we enjoy from the Pakistan Embassy in Riyadh. I am grateful for the support of all Pakistani engineers living in the kingdom and finally my personal appreciation of our Chairman IEP-SAC Engr. Jaleel Hasan for his wholehearted support and guidance in running the affairs of IEP-SAC. Finally I wish to convey my deep appreciation to all brother engineers, sponsors, advertisers and well wishers for their co-operation and support of IEP-SAC activities.

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*To spend your substance, out of love for Him, for your kin, for orphans, for the **needy**, for the wayfarer, for those who ask and for the ransom of slaves; (2:177)*

*If ye disclose (acts of) charity, even so it is well, but if ye conceal them, and make them reach, those (really) in **needs**, that is best for you. It will remove from you some of your (stains of) evil. And God is well acquainted with what ye do. (2:271)*

By the grace of Allah the Almighty, the scholarship Program for needy and academically sound students in Pakistani Engineering Universities and Colleges was launched in the year 1996. Eleven Universities and Colleges – as listed below are taking benefit from this program.

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2. University of Engineering and Technology, Taxila
3. University College of Engineering and Technology (Bahauddin Zakariya University), Multan
4. Institute of Chemical Engineering and Technology (University of Punjab), Lahore
5. Dawood College of Engineering and Technology, Karachi
6. NED University of Engineering and Technology, Karachi
7. Mehran University of Engineering and Technology, Jamshoro
8. Quaid-e-Awam University of Engineering, Science and Technology, Nawabshah
9. NWFP University of Engineering and Technology, Peshawar
10. Balochistan University of Engineering and Technology, Khuzdar
11. University College of Engineering and Technology, Mirpur (AJ&K)

This program serves all the four provinces of the Islamic Republic of Pakistan and The State of Azad Jammu and Kashmir. The Rules and Regulations, Selection Criteria and Forms can be seen and printed out from IEP-SAC website (http://www.iepsac.org). Eight (8) batches constituting 86 students had taken benefits from the scholarship scheme so far. By the help and blessing of Allah the Almighty, 51 students had graduated by benefiting from this Program.

We had started the scholarship program on a small scale and we had maintained its continuity. I take this opportunity to appeal to engineers in particular and Pakistani community in general to please join hands in this noble and just cause. It is a service to Pakistan. Let us make more effort to continue it. For more information please contact any of the member of the Awards and Scholarship Committee or any Local Council Member.

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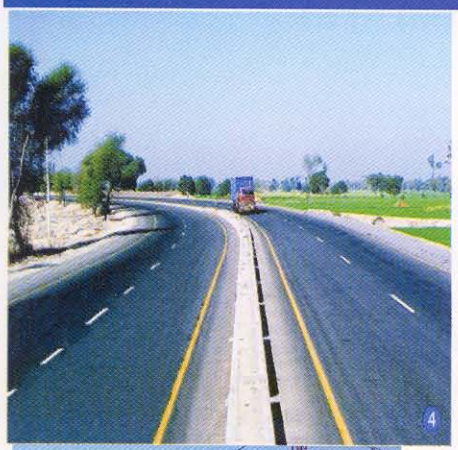

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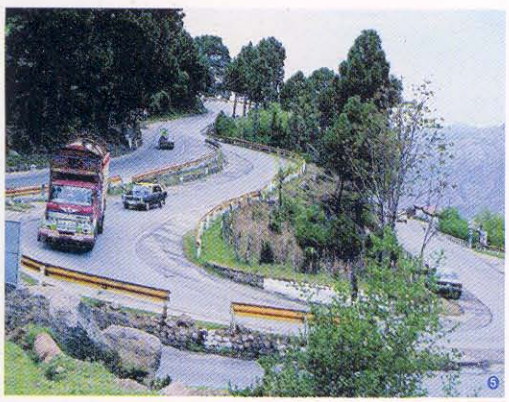

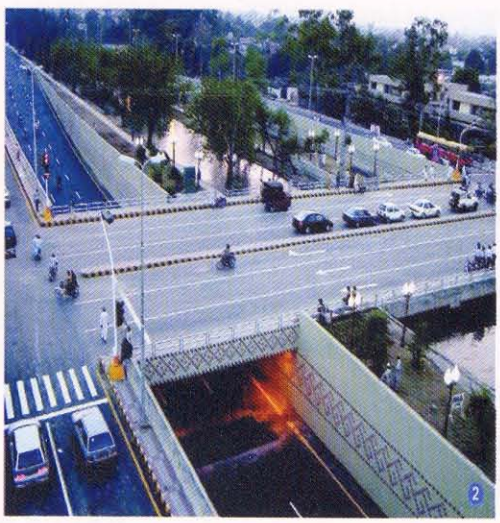

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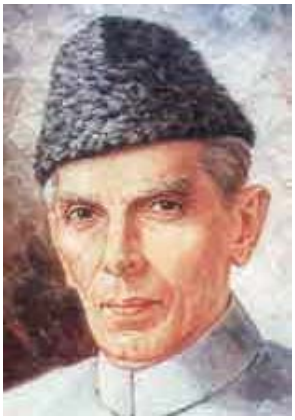

Quaid-e-Azam
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"If Pakistan is to take its proper place among the progressive nations of the world, it will have to take up a good deal of leeway in the realm of scientific and technical education which is so necessary for the proper development of the country and the utilization of its resources. The establishment of institution like the Institute of Engineers will greatly stimulate technical research and help in disseminating available information. The Institute of Engineers will not only benefit the engineers themselves by improving their technical knowledge but also bring lasting benefits to public services which they are called upon to perform.

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Gen. Pervez Mushrraf
President of Pakistan
14th August 2002

"We have now steered Pakistan out of trouble waters but we still have a long way to go. On our way out we have tried to create conditions for you to take charge and steer the ship of Pakistan into high seas at full sail. The future is with you. You are its custodians and its ultimate beneficiaries; nothing can come in your way to the path of success. Pakistan's future is bright. Your destiny is in your hands. It is entirely up to you how you ship and mould the future.

My advice to you is to build high character. Cultivate patriotic fervor in yourselves; never take Pakistan for granted. This nation came into being because millions of people were willing to sacrifice everything they had because they believed in it. Wherever you are never forget that you are Pakistanis first, hold your head high, and be proud of being a Pakistani."

CONSOLIDATION OF SOIL FOR FOUNDATION BY USING SAND DRAINS

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ABSTRACT

This paper describes the advantage of using sand drains in consolidation of saturated compressible soils. It also discusses the applicable theory, design procedure; type and technique of drain installation as well as monitoring and control procedures. The most significant part of this paper is the experimental evaluation of the validity of design and its efficiency.

INTRODUCTION

When loads are to be applied to saturated compressible soils, particularly if they affect large loaded areas, pre-consolidation of the soil to prevent excessive differential settlement is usually required when one or more of the following conditions exist:

1. Calculation of stability in un-drained conditions shows the soil to have inadequate load carrying capacity for the desired applied load.
2. Monitoring reveals that settlement is excessive and/or time-delayed with respect to the time of consolidation.
3. When the loaded area is large, the soil is heterogeneous in nature, and significant differential settlement is predicted.

One of the most effective techniques for consolidation of such soils is to make use of "pre-loading embankment" in conjunction with "vertical drains" in the existing soil. Since the soil involved in the treatment have high water content and low permeability (e.g. saturated clays or soft clayey silts), the surcharge loading initially produces an increase in interstitial pressure. This dissipates gradually, leading to soil settlement and a corresponding increase in the mechanical properties.

The time of consolidation in saturated soil of very low permeability varies directly with the length of the drainage path. As the coefficient of permeability is large in sand than that in situ soil, the sand columns called sand drains become the path of low energy potential and sub soil water flows vertically and radially through sand columns under the hydraulic gradient produced by the fill. As a result, the length of the drainage path becomes very short which helps to speed up the drainage process and consequently the consolidation process is accelerated. After about a decade of study and experience it has been found that, sand drains together with the surcharge preloading are considered as the most cost and time constrain effective solution for the consolidation of saturated compressible soil.

The sand drains are mainly used in consolidation of extensive areas of loading, such as airport runways, road embankments, large storage areas and reservoirs etc.

This paper outlines the method of designing sand drains in conformity with the characteristic of soil in situ and in compliance with the consolidation theory [2, 3]. Then the methods of execution and their merit and de-merits are briefly discussed and the quality of sand used in sand drains is elaborated. Necessary steps for monitoring and quality control are also described. An experimental programme was carried out for the verification of the validity of the design and its output data is also given in this paper. Asaoka's method [4] was adopted for the analysis of the measured settlements which confirms that the total settlement achieved was about 100% of the estimated value. Finally the validity of the design and conclusions are given.

BASIC PRINCIPLE AND THEORY OF SAND DRAINS

Sand drains or sand blankets are based on the application of the Consolidation Theory [1, 2]. Accordingly the modulus of deformation (E_S) is computed based upon stress-strain relation of the soil. The deformation or settlement (ΔH) in soil under the effect of stress (Δq) over the influence length L_0 is given by the equation:

$$\Delta H = \int_0^{L_0} \frac{\Delta q}{E_S} dZ = \int_0^{L_0} \epsilon dZ \quad ---(1)$$

Or

$$\Delta H = \epsilon L_o \quad ---(2)$$

Where ϵ is the strain. Equation 2 provides settlement but without the consideration of time required, which is a vital parameter in fine-grained saturated soil. Therefore, laboratory tests are required to estimate the compression parameter for the amount of settlement and the consolidation parameter for the settlement rate.

The time-deformation data obtained from the laboratory test are plotted on either a semi logarithmic plot or $\sqrt{t}$ plot, in order to obtain the time at some percent consolidation. The most commonly used parameters are D_{50} (50% consolidation) at t_{50} (time at 50% consolidation).

The coefficient of consolidation (c_v) is obtained from the following relation:

$$c_v = \frac{T_i H^2}{t_i} = \frac{K}{r_w m_v} \quad ---(3)$$

Where T_i is the time factor depending on % of consolidation and is about 0.848 and 0.197 for 90% and 50% consolidation respectively. H is the length of the longest drainage path for a particle of water and is taken as half of the sample thickness when the drainage is from both faces. t_i is the time required for i% consolidation to take place (t_{50} is normally used) and K is the coefficient of permeability. The primary settlement is computed either by using compressive index c_c or comp. factor c'_c which is given as:

$$c'_c = \frac{c_c}{1+e_0} \quad ---(4)$$

DESIGN OF SAND DRAINS

In order to decide the method of consolidation and use of sand drains to accelerate the process of consolidation in saturated compressible soils, the following steps are undertaken in chronological order:

1. Data about subsoil conditions are gathered which include:
   - SPT results of borings.
   - Measurements of 100 grain size distributions on samples of various layers.
   - Atterburg's limits measurements on samples of various layers.
   - Determination of topographical layout.
   - Analysis of the results of the soil survey.
   - Odometer tests to determine the compressibility ($c_c/(1+e_0)$) of the particular layer(s) to be consolidated.
   - The coefficient of consolidation c_v (m^2/sec.) adopted as the maximum value recorded under maximum applied load.
2. The height of fill to be placed in order to reach the design platform level at the end of any pre-defined time period is determined. Provision must be made for incomplete consolidation during works as well as some compensation for secondary settlement which may occur during any user-defined service time period.
3. Expected settlement and thickness of fill required above the compressible layer is estimated so that the consolidation proceeds both vertically and radially by using sand drains and 95% of the consolidation is obtained after the predetermined time.
   Based upon the soil data discussed above and using equation (1) and (2) or by using computer programme (TASDEJ) of M/S TERRASOL, one can determine the expected degree of consolidation, preloading time period, theoretical fill height, time period for compensating secondary settlement.
4. For final design of vertical sand drains, one can use the graphical method for determining the sizes of vertical drains as given in Appendix 1 which is adopted from Terrasol [5]. In this technique, based upon the following :
   i. Coefficient of consolidation c_v (m^2/s).
   ii. Preloading time period (months).
   iii. Degree of consolidation Ur (%).
   iv. Selected diameter of drains (Cm).

   One can determine the spacing of sand drains, which must be distributed along a triangular grid. Such drains, set in place using an auger, and must reach the top of the compacted, dense layer of soil. As such the required length of the sand drain could be up to 15 to 20 m.

EXECUTION OF SAND DRAINS

Three methods are used for the placement of sand drain. These techniques are:

- Driven or vibratory closed - end mandrel.
- Jetted.
- Hollow stem continuous - flight auger.

By using "Driven or vibratory closed-end mandrel" method of installation, a closed steel casing equipped with a detachable shoe is driven in the soil. The tube is filled with sand and then the tube is extracted leaving shoe in the hole. The jetting type method consists of using driven pipes where the soil inside is then jetted. The rest of the procedure is same as in Method 1. The continuous flight hollow auger method is described in the following paragraph. Some undesirable effects in the first two methods are summarized as following:

i. Smearing effect – During the extraction of the tube, there is possibility of reduction of the permeability of sand drain by clogging of the more permeable seams, specially if the mud is very laminated.
ii. Heave caused by driving – Heave (remoulding) effect in soil is considerable in a zone of about 4 x diameter of sand drain used.
iii. Extra pore pressure – Driving can generate some extra pore pressure during insertion of the casing. This excess pore pressure which is only significant close to the drain, will begin to dissipate in the sand as soon as the casing is withdrawn, which occurs in a time period of less than a few minutes.

In view of the smearing effect of driven or vibratory closed end mandrel and complex installation of Jetted sand drains, it is recommended to retain sand drains placed by hollow stem continuous – flight auger. This method is rather simple to carry out and limits the soil displacement and disturbance. The main steps for this method are illustrated in Figure1 and are as follows:

i. Placement of the equipment at the drain location.
ii. Screwing of the auger down to the chosen depth.
iii. Rotation of the auger at constant depth in order to separate it from the surrounding soil.
iv. Injection of sand while the auger is extracted (screwing is continuous during this phase).
v. Completion of the sand drains up to the platform level.

It should be noted that the rate of screwing and extraction of the auger must be such as, not to generate collapsing of the surrounding soil into the borehole.

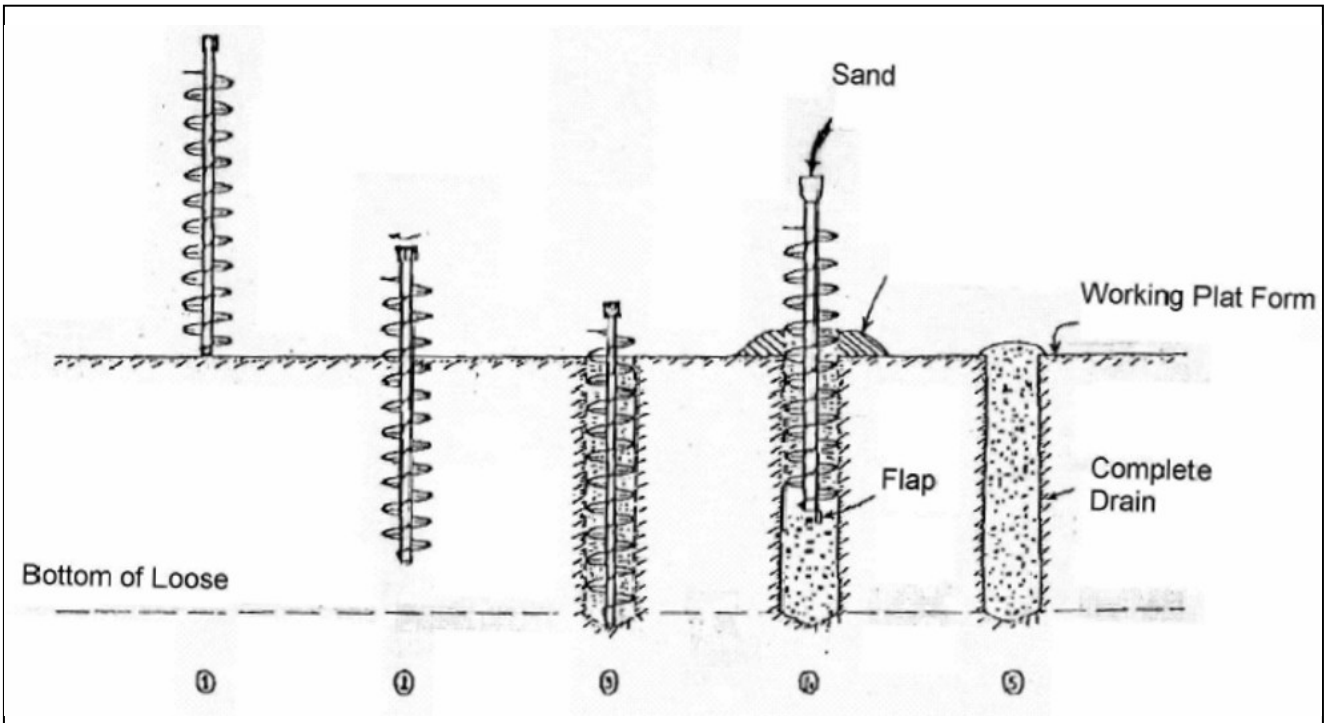


Figure 1: Execution of Sand Drains Using Hollow Stem Continuous Flight Auger

MONITORING AND CONTROL OF SAND DRAINS

Quality of sand drains must be ensured by the following monitoring and control measures:

i. Examining grain size: The sand should be clean, uniform, fine sand with a d_{50} between 0.4 mm and 1.2 mm and less than 5% particles finer than the N 200 sieve (75 μm). The d_{100} must be lower than 5 mm.
ii. Using only specified quality of sand. In case of sand drains placed with inappropriate sand, a new drain has to be carried out to replace it.
iii. Checking the topography of the saturated compressible layer of soil (sea bottom in coastal areas) along the referenced profiles before the beginning of the filling.
iv. The thickness of the fill must be checked during the filling operation along the referenced profiles. Drilled boreholes with recording of drilling parameters, static or dynamic penetrometer can be used for this purpose. Each method must be calibrated with a cored borehole or an investigation pit.
v. Settlement plates should be laid immediately after reaching top elevation of the platform. These should consist of steel plates on concrete base, embedded at least 1.0 meter under the platform grade, with a protected vertical steel rod. The settlement plates should be distributed along the refilled area at a spacing of about 50 m c/c.
vi. It is necessary to monitor that consolidation attains its design value (95% in the area with drains) at the end of the specified time. Asaoka's Method [4] enables to define the extrapolated real settlement for each location. From this result it should be verified that measured settlement represents at least 95% of the extrapolated value.

APPLICATION EXAMPLE

The author was involved in an extensive experimental program on this subject. The following trial test illustrates the design parameters, method of execution and analysis of the test results [5-6].

A site to be reclaimed occupied an approximate area of 45000 m^2 of a bay like stretch of shallow sea water with a maximum water depth around 1.5 m. Based on the available data, the maximum tide level was +0.6 MSL, and the minimum tide level -0.5 MSL.

The platform for the external work (roads, utilities etc.) was to be raised to an elevation of +2.5 MSL using a fill volume estimated around 200,000 m^3. Average distributed load at the foundation level was estimated as 50 KPa (0.5 bar).

The soil profile within the project limit is summarized in Table 1 and the available oedometer test results on samples from layer 2 are given in Table 2.

Based upon the procedure described earlier, the expected settlement and thickness of fill while using sand drains were calculated. The calculations have shown the following results related to layer 2 and expected settlement and thickness of fill required (refer Figure 2).

Table 1: Soil Profile for the Required Work

Layer	Litho logy	Thickness (m)	Levels	Density-Consistency	N (lb/ft)
1 (Only onshore)	Silty/clayey sand and gravel	3.0	+2.5 → -0.5	Medium dense	15
2	Silty/clayey sand and gravel	7.0	-0.5 → -7.5	Very Loose	6 (1) 0 (2)
3	Silty/clayey sand and gravel	10.5	-7.5 → -18	Compact/ dense	33
4	Mixture of clay, clayey sand, silt and coral	20.0	-18 → <-35	Compact	30

1. on shore
2. off shore

Table 2: Available Oedometer Test Results on Samples from Layer 2

	W_n (%)	PI (%)	e_0	c_c	$c_c/(1+e_0)$
BH3 S1 (0. – 0.75 m)	46	19	1.24	0.65	0.29
BH7 S2 (1.95 – 2.25 m)	39	15	1.02	0.28	0.14
BH2 S1 (3.5 – 4.5 m)	54	32	1.39	0.42	0.175

c_c (compressibility index)	= 0.175
c_v (coefficient of consolidation)	= 10 m^2/year
Theoretical fill height (HR)	= 4.0 m.
Expected settlement (TR)	= 0.71 m. (in 6 months)
Fill unit weight	= 18.0 KN/m^3
Total equivalent water depth	= 1.3 (Elve. = 0.8 MSL)
Preloading time	= 6 months.
Final time of secondary settlement	= 3.0 (years)
Degree of consolidation	= 1.0
ER, the residual height to be scraped at the end	= 0.25 m.

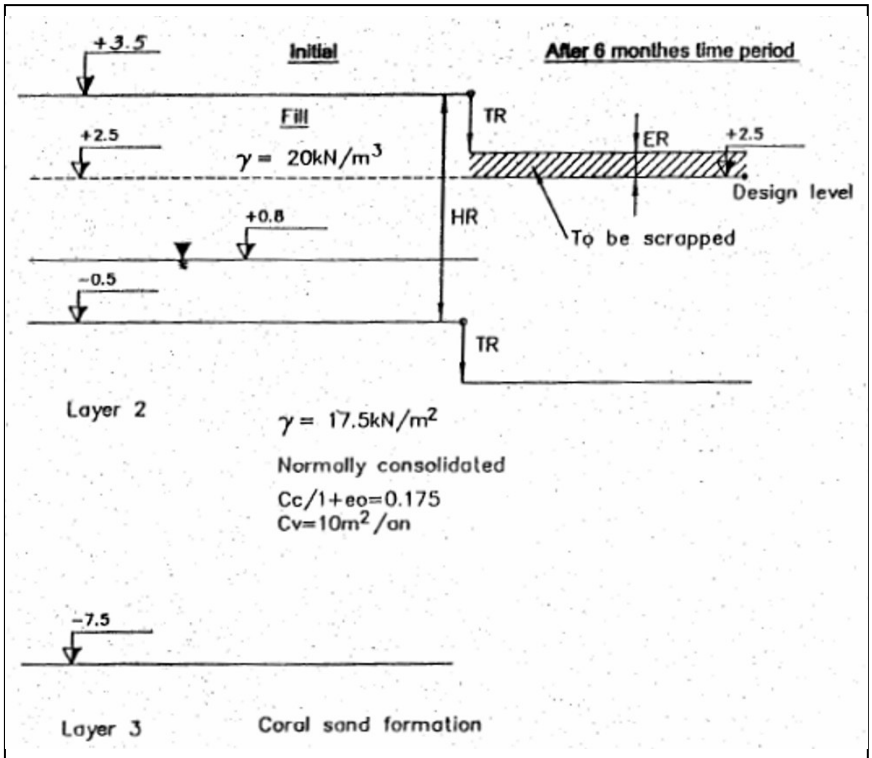


Figure 2:
Determination of the height of fill to be placed in order to reach design platform level at the end of the 6 months time period of consolidation

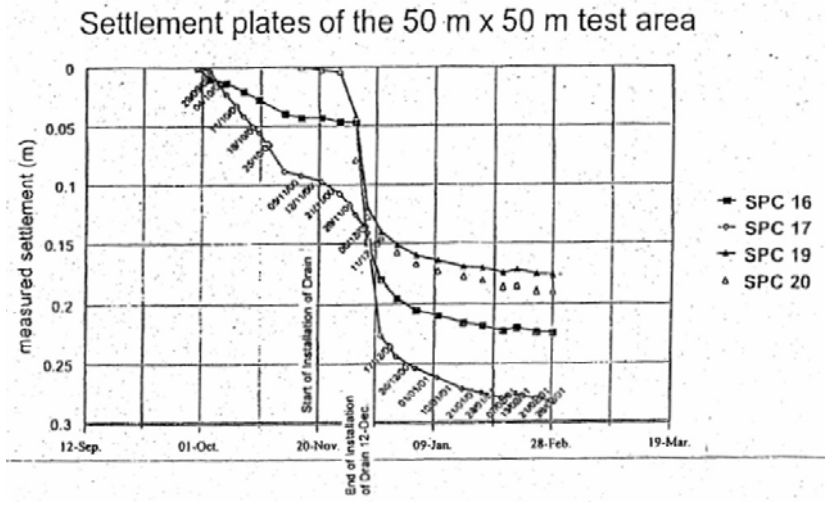


Figure 3: Settlement Vs Time (Ref. 5 & 6)

(TR+ER), defines the over height to compensate settlement, partial consolidation during work and part of the secondary settlement will be occurring in the next 3 years.

It is noticed that part of the expected settlement (TR) occurred during the filling operation. Thus a rigorous levelling at - 0.5 + 4.0 = + 3.5 MSL could lead to some additional fill to keep the fill thickness HR = 4.0 m.

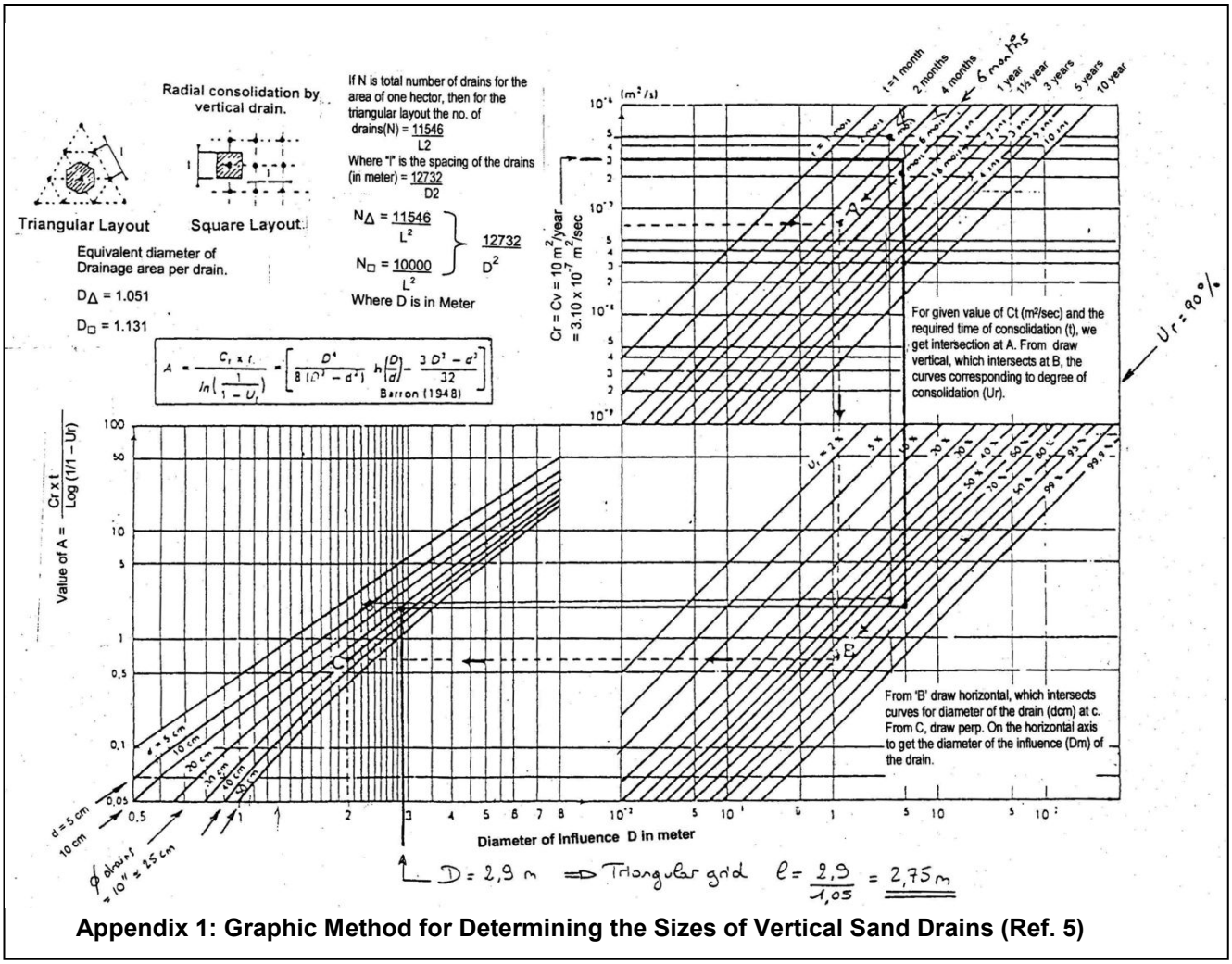
Consequently, a design of vertical drains was adopted, using Appendix 1. It was found that the degree of consolidation u = 95% can be obtained using sand drains with the following characteristics:

- Diameter of drains = 0.25 m
- Triangular grid size= 2.75 m
- Length of drains = 15.0 m

For settlement analysis, the settlement plates were located at the trial test location. For this purpose, a test area of 50 m x 50 m was selected to test the efficiency of the sand drains. In this area, installation of sand drains started on Nov. 21, 2002, and the work completed on Dec. 12, 2002.

Figure 3 summarizes all measurements in the test area from Sept. 29, one month after the end of filling and about two months prior to installation of sand drains till end of Feb. These measured settlements are only part of the total settlement, since these do not include the settlement part that occurred during the filling operation.

Observation made since the construction of drains can be analyzed by the Asaoka's method [4]. It is evident that on Feb. 28, the consolidation degree reached on any plate is higher than 99%. The estimated final settlement is between 0.18 m and 0.28 m. It can be confirmed that the total settlement achieved is nearly 100% of the estimated value. This means that around 0.4 to 0.3 m of the total settlement (or roughly 50% of the total settlement) occurred during the filling period itself and before the settlement plates were installed.



Appendix 1: Graphic Method for Determining the Sizes of Vertical Sand Drains (Ref. 5)

CONCLUSIONS

The sand drain trial test has demonstrated the validity of design and proved the efficiency to get the required 95% degree of consolidation within the imposed time period. Based on this experimental evidence, the concept was adopted for the entire project area and 100 % expected results were achieved.

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NOTATIONS

- A_v = Coefficient of compressibility ($\Delta e/\Delta p$)
- M_v = Coefficient of volume compressibility = $A_v/1+e_o$
- Atterberg's limits = Liquid limit (W_L), plastic limit (W_p) and plasticity index (PI)
- K = Coefficient of permeability (m/sec)
- r_w = Unit weight of water (pcf, Kn/m^3)
- Es = Modulus of deformation (ksf or MPa)
- C_v = Coefficient of consolidation (m^2/s)
- Cc = Compression index (void ratio Vs log. pressure)
- C'c = Compression ratio (compressibility) = $Cc/1+e_0$
- e_0 = Average in situ void ratio in the stratum for which Cc applies.
- Cr = Re-comp. index
- C'r = Re-comp. ratio
- Grain size D85 = 1.1 mm implies size for which 85% of sample is smaller and is about 1.1 mm
- SPT = Standard penetration test (ASTM D1586), no. of blows/12 inches or 30 cm penetration.
- Wn = Insitu (natural) water content.

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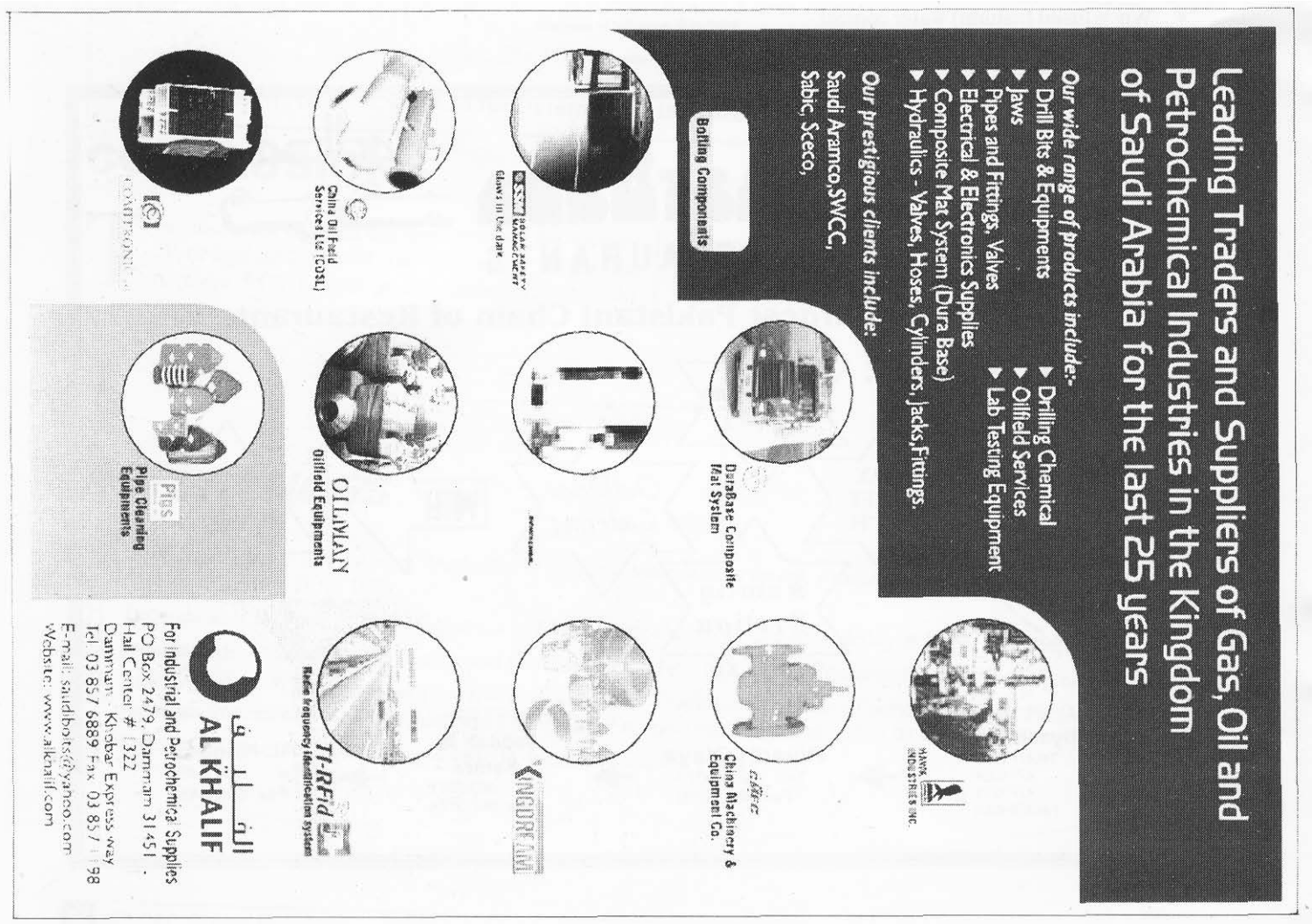
National Library of Pakistan	http://www.nlp.gov.pk	Water & Power Develop. Authority	http://www.pakwapda.com



PRINCIPLES & APPLICATIONS OF INSULATION TESTING WITH DC

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ABSTRACT

This paper describes the common insulating materials, their application and desirable properties. In addition basic initiators of insulation degradation, causes and effects of insulation failure as well as type of insulation tests and principles and applications of insulation testing are discussed. Finally paper focuses on testing insulation quality with DC and various types of DC insulation tests performed worldwide are reviewed.

INTRODUCTION

Insulation is the isolation between parts of an electrical power system. It may be solid, liquid, gas or vacuum. No insulation is perfect, therefore, a certain magnitude of current does flow through it. Such a current may be insignificantly small for most practical purposes but it is the basis of insulation testing.

Insulation degrades over a period of time because of various stresses imposed upon it during its normal working life. The insulation of electrical equipment is designed to withstand these stresses during the working life of insulation. Abnormal stresses can cause an increase in the natural aging process that can severely shorten the working life of the insulation. For this reason, it is a good practice to perform regular testing to identify the increased aging if taking place, the cause of aging and also to identify the most appropriate actions to correct the insulation.

Most electrical equipment in the utilities, industries, and commercial power systems use either 50 or 60 Hz AC. Because of this, the use of an AC source to test insulation seems to be the logical choice. However, insulation systems are extremely capacitive and AC test equipments are bulky and costly, DC has considered more suitable than AC. The DC test equipment is almost trivial in size compared with AC test equipment. For example, a one-mile length of cable being tested at 50 kV AC would require test equipment with a capacity of between 400 kVA and 500 kVA. A DC test at 50 kV would require a capacity of 50W using test equipment that is significantly smaller and easier to use.

INSULATING MATERIALS AND THEIR PROPERTIES

A substance through which conduction of electric current does not take place or is negligible, and in which an electric field can be maintained with a minimum loss of energy is called dielectric or insulating material.

Polyvinyl Chloride (PVC), Polyethylene (PE) and Cross-Linked Polyethylene (XLPE) are solid insulating materials used for cables and conductors. Epoxy resin, unsaturated polyester resins (with 60-70% filler) and polyurethane resin (with 60-70% filler) are used for cast resin mouldings. Ceramic insulating materials are used for post insulators, insulators and bushings. Silicone rubber is used for cable terminations and corona-resistant insulation tubing. Kraft paper, pressboards, laminated wood and insulating tapes are used for transformers, generators and motors. The important properties of solid insulating materials are density, bending strength, tensile strength, impact strength, linear thermal expansion, maximum temperature, tracking resistance, breakdown field strength, dielectric constant and resistivity.

Mineral oil, silicone liquid, HKT mineral oil and Synthetic ester are liquid insulating materials. Their important properties are density, viscosity, pour point, thermal conductivity, coefficient of expansion, dielectric constant, flash point, fire point, breakdown strength, dissipation factor, spontaneous ignition temperature and flammability.

Air (Dry) and SF_6 are gaseous insulating materials. Density of air at Normal Temperature and Pressure (NTP) is 1.205 and its breakdown field strength is 2.1 kV/mm (50 Hz). It is used as insulating and arc-extinguishing medium in air-break circuit breakers at atmospheric pressure. While in air blast circuit breakers, pressurized air is used as an insulating and arc-extinguishing medium. SF_6 is an inert gas, colourless, odourless, non-inflammable and non-poisonous. At NTP, SF_6 gas has a dielectric strength and density equal to 2.8 and 5 times those of air at the same conditions. SF_6 is chemically stable and it is used as insulating and arc-extinguishing medium in switchgear.

BASIC INITIATORS OF INSULATION DEGRADATION

The basic initiators for insulation degradation are electrical stress, mechanical stress, chemical attack, thermal stress and environmental contamination. Normal cycles of operation lead to aging through these mechanisms. Even air oxidizes organic materials while the ingress of moisture, oil and salt degrades effectiveness rapidly. This is therefore, one of most important problems, which must be identified on routine test basis. Electrical stresses, particularly sustained over voltages or impulses can lead to discharges in voids, which may thereby expand and can initiate electrical treeing. The aging of insulation is a slow process of degradation as these factors interact with each other in a gradual spiral of decline. At some point, dependent on both original and operating conditions the decline may speed up significantly.

CAUSES AND EFFECTS OF INSULATION FAILURE

Insulating materials play a critical role in the life of electrical equipment. The deterioration of insulation is one of the primary causes of electrical equipment failure. About 60% failures are caused by insulation problem. The failure of insulation while in service may cause significant damage to equipment and to the system to which it is connected. It can cause dangerous voltage, fire, high fault current and explosion, damage to equipment and property, personnel injury and fatal accident. By applying insulation tests, deteriorated insulation can be identified before failure occurs.

Main causes of insulation failure are mechanical damage, pinholes, cracks, dielectric contamination, moisture and humidity, corrosive vapors, grease and oil, vibration, temperature cycling, excessive overloads and temperature rise, excessive voltage stress due to over voltage, surface contamination, partial discharge, tracking, electrical treeing, ferroresonance, aging, inadequate workmanship, unqualified testing personnel, mishandling and manufacturing defect.

TYPE OF INSULATION TESTS

Insulation testing is performed during acceptance test, factory routine test, pre-commissioning, preventive / predictive maintenance and after repair (breakdown maintenance). Insulation that has been worked on in any way should be tested before returning to service. A brief description of each type of test is as follows:

a. **Type Test:** Type tests are performed to the first unit manufactured by a vendor to a given specification. It is presumed that every such equipment would also comply with the type test, since its design is unique. Insulation type tests are: full wave impulse withstand test, 1.2/50 µs wave and switching impulse withstand test, 250/2500 µs wave. Switching impulse test is applicable for system voltages ≥ 220 kV.
b. **Special Tests:** Special tests correspond to particular service conditions or investigations. Chopped impulse wave withstand test and partial discharge test are insulation special tests.
c. **Factory Routine Test:** Routine tests are carried out on every equipment without exception before shipment. Insulation routine tests are: measurement of insulation resistance (spot test and time-resistance), power frequency voltage withstand test and induced over-voltage withstand test.
d. **Pre-commissioning Test:** These tests are conducted at site in accordance with an approved method statement before commissioning. Insulation pre-commissioning tests are: measurement of insulation resistance and polarization index, DC Hi-Potential Test and power frequency voltage withstand test at 80 % of the values as indicated in IEC 60298, Sub-clause 7.1 (refer IEC 60298, Annex DD) or at 75 % as per ANSI standard. It is recommended that utilities, industrial and

commercial clients should review and replace DC Hi-Potential test with VLF Hi-Potential test.

e. **Preventive Maintenance Test:** As an old age saying goes "*A stitch in time saves nine*", a regular periodic preventive maintenance may correct the situation in time and can eliminate the need of consequent major repair. For example, with good preventive maintenance and proper loading, a power transformer gives a service life of over forty years.

f. **Predictive Maintenance Test:** It is a development of "Stitch in time" philosophy that uses data from testing and monitoring to adjust the maintenance activity in such a way that it is carried out at appropriate time whenever it is required instead of after a fixed interval of time.

TESTING INSULATION QUALITIES WITH DC

Let us see how DC voltage affects insulation of electrical equipment. With DC voltage insulation may be modeled as shown in Figure1. When switch S1 is closed, the DC supply is connected to the insulation system. In the DC model as compared to AC an extra capacitor has been added (dashed lines). The current that flows through this new capacitor is called dielectric absorption current (I_{da}). Figure 2 shows the time relationship for the three currents I_c, I_{da} and I_r in the body of insulation.

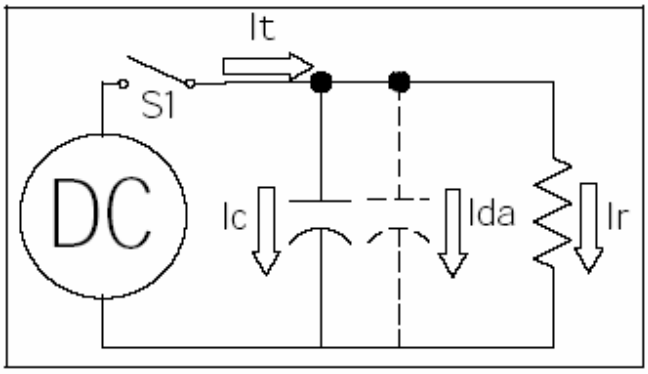

Figure 1: Insulation with DC Voltage Applied

Capacitive Current (I_c)

The capacitive current charges the capacitance in the system. It normally stops flowing a few second after the DC voltage is applied. In low-capacitance equipment, the capacitive current is higher than conductive leakage current, but usually disappears by the time we start recording the data. Because of this, it is important to let the reading "settle out" before recording it. On the other hand when testing high capacitance equipment the capacitive charging leakage current can last for a very long time before settling out.

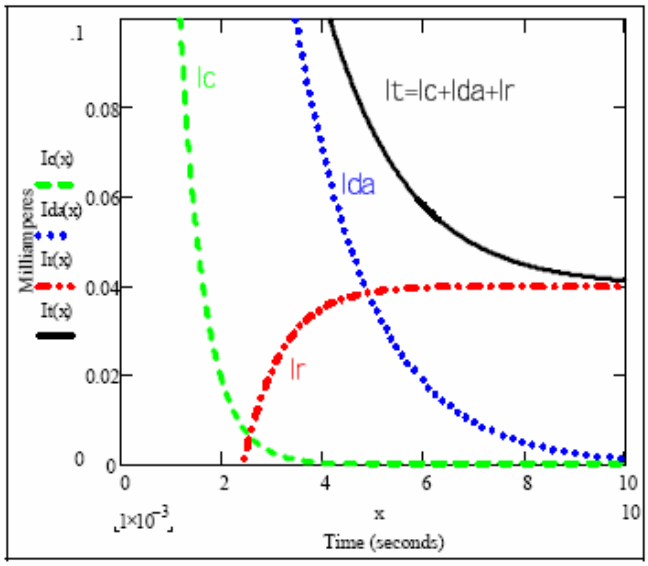

Figure 2: DC Current Flow in Good Insulation

Dielectric Absorption Current (I_{da})

Absorption current is caused by the polarization of molecules within dielectric material. In low-capacitance equipment, the current is high for the first few seconds and decreases slowly to nearly zero. When dealing with high capacitance equipment or wet and contaminated insulation, there will be no decrease in the absorption current for a long time.

Resistive (Leakage) Current (I_r)

This is the electron current flow that actually passes through the insulation. It consists of two components:

a) Conduction leakage current I_{lc} and

b) Surface leakage current I_{ls}.

In good insulation, the resistive (leakage) current flow will be relatively small and constant. In bad insulation the leakage current may be fairly large and it may actually increase with time.

PRINCIPLES OF INSULATION TESTING

The principle concerns to be observed when testing with DC is the possibility of damaging otherwise good insulation. The following points should be observed during testing:

1. Sudden application or removal of the voltage creates a very large dV/dt, and causes an abnormal amount of stress. The test voltage should be applied and removed gradually.

2. If a large over-voltage of the order of 2 or more times normal is applied to some insulation systems, the smaller air voids in the insulation will become charged. If the insulation is then suddenly re-connected to the power system, it may fail due to the addition of the system voltage to the still charged voids. Even if the insulation does not immediately fail, it will be stressed and may lose life. It may happen during pre-commissioning and field maintenance. To avoid this problem, insulation should always be drained off DC test voltage for one to five times the length of time that the test voltage was applied before it is re-energized.
3. Test leads must be in good condition.
4. Accuracy of megger must be checked by performing zero and infinity checks.
5. During test, Guard terminal and test leads are never touched. Also test lead should not be pressed under feet.
6. Test leads should not be allowed to touch each other or any other object because this will induce leakage paths.
7. Sharp points at the test lead connections should be avoided to prevent corona discharge.
8. Instrument test jacks should be deep so that unwanted leakage does not occur between the terminals.
9. For precise readings, Guard terminal should be used.
10. Proper testing sequence should be followed.
11. Approved epoxy stick should be used for discharging the test object.
12. After completion of test, all readings should be corrected at 20^{o}C. Tables of correction factors or field rule of thumb may be used that the insulation resistance will halve for each 10^{o}C rise and vice versa for apparatus containing immersed oil insulations. For apparatus containing solid insulations, the insulation resistance will halve for every 15^{o}C rise in temperature and vice versa. In oil-immersed transformers, temperature of the top oil and in dry type transformers, ambient temperature is taken as the insulation temperature.
13. Humidity will not generally affect on insulation resistance unless the temperature is very low close to the dew point and condensation forms on or in the insulation.

INSULATION TESTING APPLICATIONS

Its application include testing of switchgear, transformer, generator, motor, CTs, VTs, cable, wiring, lighting circuit, control equipment, appliances, meters and relays. Each type of equipment requires its own unique testing procedure, conforming to different test standards.

INSULATION DC TESTS

There are numerous tests for assessing the insulation quality. This paper discusses diagnostic insulation DC tests.

DIAGNOSTIC INSULATION DC TESTS

Diagnostic insulation DC tests electrically simulate the insulation and measure the response. Dependent upon that response, we can draw some conclusions about the condition of insulation. These tests are:

- Spot Test
- Time-Resistance Test such as: Polarization Index (PI) and Dielectric Absorption Ratio (DAR)
- Step Voltage Test
- Discharge based Tests such as: Dielectric Discharge Test, EDA Test and Isothermal Relaxation Current Test (IRC Test)
- DC High Potential Test
- Surge Test

Spot Test

The spot test is the simplest insulation test. It is performed for go / no go testing and historical records. It is temperature dependent and has humidity effect. The test voltage is applied for a short, specific period of time; typically 60 sec as I_c and I_{da} will have decayed by this time and a reading is taken.

(Insulation Resistance) $IR = V_{dc} / I_{dc}$
$IRinitial = V_{dc} / (I_c + I_{da} + I_{lc} + I_{ls})$ and
$IR_{60sec} = V_{dc} / (I_{lc} + I_{ls})$ or
$IR_{60sec} = V_{dc} / I_r$ where $I_r = I_{lc} + I_{ls}$

For large, HV and EHV transformers, reading after 10 minutes is recorded. Values of insulation resistance less than manufacturer's minimum or rated voltage + 1kV in megaohms should be investigated. Commonly used DC test voltages for routine maintenance are as follows:

Table 1: DC Test Voltages

Equipment AC (Rating)	Recommend DC (Test Voltage)
24 – 50V	50 – 100V
50 – 100V	100 – 250V
100 – 250V	250 – 500V
251– 600V	500 – 1000V
601 – 5000V	2500V
5001 – 12,000V	5000V
> 12,000 Volts	10,000V

Time-Resistance Test

1. Polarization Index (PI)

The ratio IR_{60sec} / IR_{15sec} or
IR_{10min} / IR_{1min} is called Polarization Index. This test determines the elasticity of the ground insulation. When placed in an electric field, molecules of the good insulation should align with that field (see Figure 3). If the insulation is aged, hard, and brittle, no polarization can occur. PI is fairly independent of temperature and often can give conclusive information without records of past tests. Successive readings at specific time be taken and differences in the readings be noted. IEEE STD. 43-2000 recommends following minimum acceptable values for the various thermal classes of motor insulation:

Class A: 1.5, Class B, C, F and H: 2.0

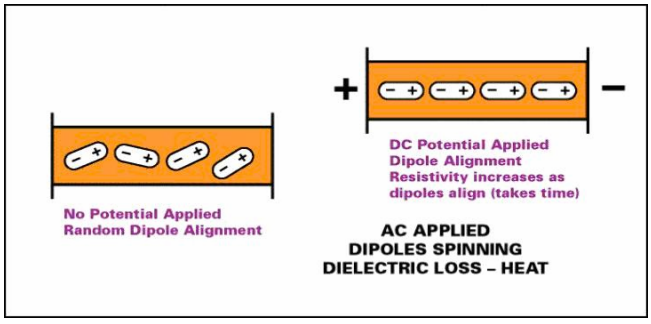

Figure 3: Alignment of Polarized Molecules

2. Dielectric Absorption Ratio (DAR)

The ratio IR_{60sec} / IR_{30sec} is called Dielectric Absorption Ratio.

DAR = IR_{60sec} / IR_{30sec} or

DAR = $(I_{da} + I_{lc} + I_{ls}) / (I_{lc} + I_{ls})$

= $(I_{da} + I_r) / I_r$

When an electric field is applied some ions are able to move and some dipoles align themselves in the field within the insulating material. These charging effects cause absorption current which has a long time constant. DAR gives an idea about quality of insulation. If DAR is:

< 1	Failed
1 to 1.25	OK
1.4 – 1.6	Excellent

Step Voltage Test

The step voltage test involves insulation resistance testing at various voltages. The recommended ratio for the test voltages steps is 1 to 5. At each step, the test voltage is applied for 60 seconds. The application of increased voltage creates electrical stresses on internal cracks. This can reveal aging and physical damage even in relatively dry and clean insulation that would not have been apparent at lower voltages. Good insulation should withstand an increase in over-voltage stress and its resistance should remain approximately the same during testing with different voltage levels. If resistance values decrease at higher voltage levels, it is an indication that insulation quality may be deteriorating due to dirt, moisture, cracking, aging, etc.

Discharge Based Tests

1. Dielectric Discharge Test

The Dielectric Discharge (DD) Test measures the discharge current 60 seconds after the insulation test is finished. This test assesses the aging and deterioration of insulation. The result depends on the discharge characteristic therefore; the test is largely independent of any surface contamination. The charge that is stored in the sample is measured during the discharge phase. This is converted to a figure of merit, which gives a figure for the quality of insulation, independent of the test voltage.

The DD value is defined as (in $\mu AV^{-1}F^{-1}$):
DD = Current after 1-minute (μA) / {Voltage (V) x Capacitance (μF)} = I 1-minute / (V x C)

In multi-layer insulation the DD test result can show how similar the layers of insulation are. In the case of insulation failure in a single layer of insulation the leakage resistance will decrease but the capacitance will remain the same. This type of fault is not possible to detect from a standard insulation test because the overall resistance will remain high due to the other high resistance layers. Similarly, other tests such as time-resistance measurements, step voltage test or capacitance measurement will not necessarily show any particular problem. Measuring the discharge current can show when the resistance-capacitance characteristic is incorrect. A low DD value shows that the re-absorption current is decaying quickly and the time constant of each layer of insulation is similar. A high value of DD shows that the re-absorption current exhibits long relaxation times, which may point to a problem with the insulation. Typical conditions from practical research, primarily carried out on generators, arrived at the figures of merit in the table below.

DD Value (in $mAV^{-1}F^{-1}$)	Insulation Condition
>7	Bad
4 – 7	Poor
2 – 4	Questionable
<2	OK

2. Isothermal Relaxation Current Test (IRC Test)

This test has been derived for testing cables and grew out of the problems associated with pressure testing of plastic cables. The IRC test uses a 1kV test voltage for 30 minutes to polarize the insulation under test. The polymer polarization traps charge at specific discrete energy levels and during the discharge process these energy levels give rise to different time constants in the discharge current. The major use of the effect in the IRC test is to look for the time constant associated with water trees in degraded XLPE cable material. The Relaxation Current occurring after the capacitance has been discharged is digitized for processing in PC based software. The software processing is based on a modeling technique, which converts the current into charge and plots this charge against time. The total charge plot is then treated as a composite of standard shapes whose time constants are "fitted" to the composite curve by iteration. Aging of the cable is identified by the relative values of time constants. The test was initially developed using artificially aged cable and now has been applied to operational XLPE cables.

3. EDA Test

This test was developed for motors and generators, but it has much wider applicability than the simple Dielectric Discharge test. The EDA test also monitors currents, voltage and capacitance and the software calculates a wider range of parameters from both charging and discharging cycle at two voltages, to give enhanced information on insulation condition.

The EDA test therefore, combines attributes of Polarization Index, Step Voltage and Dielectric Discharge tests to give the broadest diagnostic information possible. The software also takes information on insulation type and motor operation history to assist with the diagnosis.

DC High-Potential (Hi-Pot) Test

A Hi-pot test is a deliberate application of an excessive amount of voltage intended to stress the insulation system. The test voltage during a Hi-pot test can be either AC or DC. A recommended test voltage for Hi-pot testing a motor, generator or transformer is twice the AC line voltage plus 1000 volts. This test voltage is consistent with IEEE 95-1977 (for test voltage greater than 5000 volts), and IEEE 43-1974 (test voltages less than 5000V). For new windings or rewound motors, the test voltage is sometimes increased by a factor of 1.2 or even 1.7. This provides for a higher level of quality control on the work performed. During the application of over-voltage the instrument measures the flow of current through the insulation. If the current is in excess of a preset level, a failure conditions is signaled.

The DC Hi-pot test can uncover insulation weaknesses that might not necessarily be detected in an IR or PI tests. In addition to measuring overall insulation resistance to ground, it provides information on insulation dielectric strength. In this sense, it can detect insulation weaknesses that are likely to fault to ground if subjected to the high transient voltage surges that commonly occur on industrial power systems.

This test is ideal for detecting workmanship errors, design problems as well as component spacing problems. The areas where Hi-pot tests are typically used include: production line, research and development labs, incoming inspection areas, pre-commissioning and maintenance and repair. In Hi-pot testing of cable, the DC test voltage is applied in a minimum of four steps (each step approximately equal to the rated r.m.s voltage of the cable) of one minute each except for the final test voltage that shall be maintained for fifteen minutes. Max. Hi-pot test voltages for cable are as below.

Equipment Rated Voltage (KV)	Test Voltage AC	DC
2.5	6.0	10.0
5.0	14.0	24.0
15.0	27.0	46.0
35.0	60.0	102.0

The maximum recommended value of field DC test voltage for cables is: 1.7[0.75(2 x equipment maximum voltage + 1kV)]

Surge Test

It is the only test that looks at inter-turn winding insulation condition of motors. It is performed to detect insulation damage between turns within a motor's winding. The surge test consists of applying a short, fast rise time, and high current impulse to a winding. This high-rise time impulse will induce a voltage difference between adjacent loops of wire within the winding. If the insulation between the two loops of wire is damaged or somehow weakened, and if the voltage difference between the wires is high enough there will be an arc between the wires. The arc is detected by observing a shift to the left in the surge waveform. The voltage or amplitude of the surge wave pattern is also reduced due to the decrease in inductance of a coil with a fault between turns.

CONCLUSIONS

The insulation of an electrical power system is tested for system performance, system safety, system reliability and economic asset management. The insulation degradation cannot be eliminated but minimized if the basic initiators are controlled, causes of aging are identified and appropriate corrective actions are taken in time.

There are variety of test methods and testing equipment that can be used for assessing the condition of electrical insulation. One test by itself does not provide conclusive

proof that insulation under test is defective. Normally, several dielectric tests are performed on the same insulation and each test provides additional information that should be evaluated before the insulation is determined to be serviceable or suspect. Testing sequence is very important and it should be considered for adequate testing. For example, the suggested testing sequence for a motor is: (1) Winding resistance, (2) Insulation resistance, (3) Polarization Index, (4) Step Voltage and finally (5) Surge test. During dielectric test, improper application and removal of test voltage may deteriorate the insulation and increase it's aging. It is very important that only qualified personnel perform testing. All the diagnostic tests mentioned in this paper except surge test see the major insulation. The surge test is the only test that looks at the turn-to-turn insulation.

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SRW: A NEW DIMENSION IN LANDSCAPE DESIGN

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ABSTRACT

Segmental Retaining Walls (SRW) are reinforced-soil earth-retention structures, sort of composite structures relying on the principles of soil-structure interaction. These are extensively tried & tested and have proved to be an useful alternative technique for soil-stabilization, earth-retention and are fast replacing the conventional concrete retaining walls; principally due to the merits offered by it in trusted performance, economy and ease of construction. This type of design is already very popular in North America, where this technique is being commonly used for the earth-retention problems. This system is of great interests to the academics & the industry and if introduced in the Kingdom of Saudi Arabia, this has great potential of becoming popular here as well. This paper is therefore focused to generate awareness about SRW in the region.

INTRODUCTION

Segmental Retaining Walls (SRW) are dry stacked, mortar-less walls made of 100 % low absorption, high strength concrete units. SRWs are comparatively more economical and easier to install than cast-in-place concrete or conventional masonry walls. Its principal features are as follows:

- It is mortar-less.
- No footings are required.
- It is flexible, and tolerates movements.
- Walls up to 1.2 m high can be built without any geo-synthetic soil reinforcement, as shown in Figure 1.
- Walls greater than 12 m height can be built with geo-synthetic soil reinforcement, as shown in Figure 2.
- It is easy to build and economical as compared to conventional concrete walls.
- Curves, corners, stairs, columns and freestanding walls can be easily created with great variety of commercially available design patterns.

SRW is of interest principally to Landscape Designers, such as landscape architects, site/civil engineers, geotechnical and structural engineers, while contractors & inspectors also find interest in it. With the popularity of and trust & faith in SRW, vis-à-vis its applications, as retention structures in public gardens, community & private homes, highway earth retention structures, etc., it is now possible to create beautiful landmarks with comparative ease & economy. Until recently, it used to be too expensive to design something to make it look nice & appealing. However, today the hard-scape is becoming more of a landscape. And, as rightly said by some engineers, "we're seeing a boom in what we call pretty structural engineering".

Today in USA and other parts of the developed world, SRW is considered the one and the only ticket to many a challenging problem faced to the landscape architects, geotechnical and structural engineers. To name a few real life challenges, the first one is building of an upscale town-house community project called HIGHLANDS on top of a 19 m cliff in northern New Jersey. Being located on a cliff, the project required some innovative techniques for transforming mountainous rock into livable space together with ensuring the stability and integrity of the surrounding terrain. To surmount these and other daunting challenges, SRW system was selected for its design flexibility, aesthetics, ease of installation and durability. SRW system was thus considered the perfect fit and using the same as compared to a cast-in-place or any other type of wall

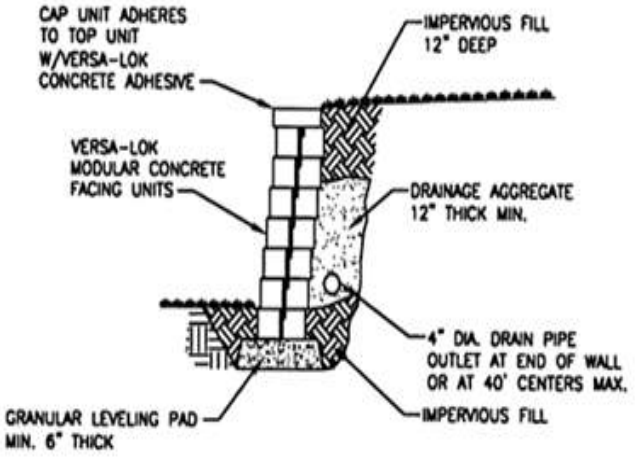

Figure 1: Typ. Section-Unreinforced Retaining Wall

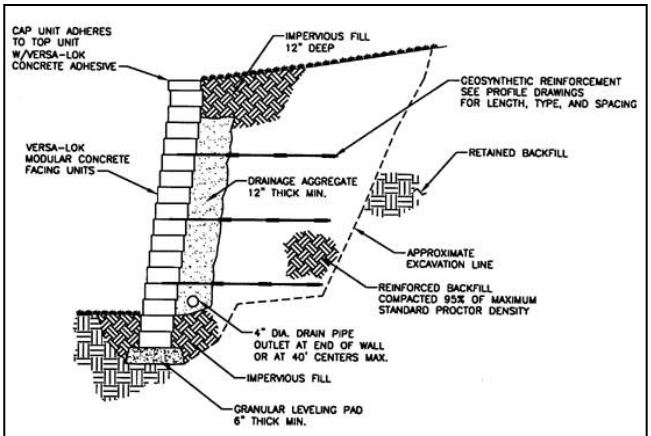

Figure 2: Typ. Section-Reinforced Retaining Wall

system was by far the most aesthetically pleasing and cost-effective choice [1].

In yet another equally challenging project, the Irvine Company (Orange County, California) was faced with a challenge to develop the steeply sloping site, at Newport Coast to develop a luxury community. SRW with integral space for vegetation helped the company realize its goals. Developing the hillside coastal site for Newport Coast were posed with numerous challenges, chiefly: preserving the appearance of a natural hillside, tackling the technical challenges of drainage, slope stability, consideration of floodplains and wetlands, besides the structural issues that building in the earthquake zone entails. One option was to go ahead with Mass Grading with linear tiers; this was not considered for obvious reasons. However, choosing SRWs allowed the Company to adopt Contour Grading, in agreement with the natural topography of the site, with economic benefits and reduced site development.

The scope of this paper is focused to introducing this new & novel method of earth-retaining system to the engineers, the academics, and to a layman who in the capacity of a home-owner, a client and/or a commercial builder would be interested in considering adopting this in any of his/her project. For this purpose a discussion follows on the evolutionary history of SRW, its design philosophy, its construction details and information on SRW standards the future design code that is in the process of its formulation.

EVOLUTIONARY HISTORY OF SRW

SRW has a remarkable evolutionary history that dates back to early-to-mid 1970s in Canada where it was basically invented by Angelo Risi, the founder of Risi Stone Systems. The Segmental Concrete Wall units produced on concrete products machines were marketed then, in USA and Canada, under the name of Pisa Stone, after the Leaning Tower of Pisa in Italy. In one of his articles Angelo Risi described how and when the idea of SRW came to his mind. He wrote, "*I noticed, especially in the street where I lived, that the municipality used to tear down and put back up, almost every second year, some rubble walls*". He continued, "*Sometimes they would use broken pieces of sidewalk stacked up*". According to him, "*with the frost we have in Canada, invariably the wall would start moving around and in a couple of years they would be rebuilding it all over again*". He added, "*I thought to myself, my uncle is in the business, and if he could build something that would lock itself into place, that would solve the problem of constantly rebuilding these walls*". He further added, "*We came up with the idea of basically a slab with a broken face and a tongue and groove to it so that they would lock into each other. We tried it, and we called it Pisa Stone after the Leaning Tower of Pisa in Italy*". This is how SRW system was conceived and invented by Angelo Risi. The result was well received and, over the years, Risi and his brother Tony bought their uncle's concern and created Risi Stone Manufacturing, Thornhill, Ontario. They started making Retaining Wall systems, as well as continued some products that their uncle was making at that time. Less than a decade later, a couple of others (that includes two of the major industry leaders of the US today) introduced their own proprietary systems in the US and the growth of the industry began in earnest.

By the end of the 1980s, there were several more proprietary SRW systems licensed in the US and in other parts of the globe. And, from the late 1980s SRW use grew at a rate of 20 to 25% annually. In 1998 the National Concrete Masonry Association (NCMA) organized a meeting of over 30 stakeholders in the SRW industry. The group consisted of concrete products manufacturers, licensors, material vendors, engineers and others with interest in the SRW market. The consensus of the group after approximately six hours of deliberations was that use of SRW would double by 2003. This indeed did happen more or less the same. The evolutionary history of SRW and the achievements of Angelo Risi is summed up in one beautiful expression, "*After all these centuries, it only took imagination and engineering, and a desire to help his*

Plate-1: Landscaping in Front of a Villa

Plate-2: Landscaping in Front of a Villa

Plate-3: SRW for a Golf Course

Plate-4: SRW for a Community Park

community save money, for an inventor to develop the Segmental Retaining Wall system" [2].

Segmental Retaining Wall units are considered a high-end value-added product, which have evolved into a significant part of the product mix of many concrete masonry-manufacturing operations. It has especially grown during the past 15-20 years to become a popular choice as an earth-retention structure, replacing in most applications the conventional concrete retaining wall, and becoming a popular alternative in the landscape designs. But all these didn't occur overnight. It is stated that the ongoing success of the SRW is a direct result of the investment of the major concrete industry licensors into the multi-faceted marketing efforts. It is a fact that this is the actual fuel that drives the industry. From education and design guides to exhibits at trade shows, these significant financial & human resources maximize the popularity of SRWs. It is also agreed that the success of SRWs is a blueprint that can be emulated in all aspects of the concrete business everywhere. Blending attractive, quality and proven products with qualified people, and investing in strong marketing measures, all add up to long term financial gains and industry growth.

One may ask as to why does the use of SRW systems continue to grow. The answer to this difficult question is rather simple. That is, the SRW systems are in fact environmentally friendly, easy to construct, aesthetically appealing & economically proven, and offer flexibility and versatility in design. In June 1998, Drexel University in Pittsburgh, Pennsylvania published Geosynthetic Research Institute Report # 20, entitled, "Earth Retaining Walls Costs in the USA", authored by Dr. Robert M. Koerner et al, which documents the relative costs of various styles of retaining wall systems. The SRWs are stated to be clearly the most economical one [3]. Some pictures of use of SRW in landscaping are shown as above.

DESIGN PHILOSOPHY

SRWs systems are basically a sub-set of Mechanically Stabilized Earth and for all-purpose are principally Earth Retention Structures. For normal conditions, experience has shown that SRW systems work solely as Gravity Systems, where unit weight provides resistance to earth pressures. Frictional forces between units and tight pin connections hold units together so walls behave as one coherent structure. When weight of units alone is not adequate enough to resist soil loads, horizontal layers of geo-synthetic materials are used to reinforce the soil behind walls. The choice of type, thickness, embedment lengths, and number & spacing of layers of these synthetic materials are all dependent on actual ground conditions and are determined by proper design undertaken by structural engineers. Design of SRWs is a serious subject and is dependent on several factors including: soil parameters at the site such as unit weight, internal friction angle and cohesion, ground water table, and the height of wall.

It is important to mention here that globally SRWs are designed using the NCMA Design Manual for Segmental Retaining Walls known as NCMA Publication # TR-127A. This Design Manual is recognized worldwide as a valid design methodology for SRWs. In fact, the NCMA Design Manual is cited by the US Army Corps of Engineers as an acceptable Design Methodology for SRWs on Corps' projects. Reference to provisions in the Design Manual are also found in the American Association of State Highway and Transportation Officials (AASHTO) which is adopted by nearly all the State highway transportation departments within the US and is also often specified in local commercial and international projects. This Design Manual is also supplemented by a Design Software for Segmental Retaining Walls termed as NCMA Publication # CMS-11711. There is also a Seismic Design Manual and Software (NCMA Publication # TR-160 + CMS-11711) for undertaking design under seismic loading conditions. NCMA Publication # TR-212 (Retaining Walls—A Building Guide and Design Gallery) is yet another bestseller. This was printed in 2003 and this is by far the only authentic book on the subject of SRW installation. In addition, the book includes a gallery of beautiful completed SRW projects from commercial to residential and engineered to do-it-yourself. All these Design Manuals remain incomplete without the Segmental Retaining Wall Drainage Manual (NCMA Publication # TR-204), which extends the Design Methodology to hydrostatic loading that may be required to address the presence of sub-surface water and surface water infiltration. This is also focused to help prevent poor SRW performance when surface and ground water issues are not properly addressed. It is worth noting that SRW performance problems are commonly attributed to the failure to properly route water during and after construction or account for hydrostatic load during the design phase. This Manual ensures adequate guidance is available to the design community and preserves the integrity of the SRW industry.

The design analysis of SRW employing the NCMA Design Manual for Segmental Retaining Walls considers the External Stability against sliding and overturning. It also considers Internal Stability and Facial Stability of the reinforced-soil mass. This Design Manual performs Internal and External Stability analysis using the recommended minimum factors of safety in this manual.

Global Stability analysis is also important in SRW design, particularly when walls are over 2 m tall, are tiered, involve slopes steeper than 3H:1V, or are to be constructed on soft soils. It involves the general mass movement of the wall structure and the adjacent soil. This particular aspect of Stability Analysis of SRW is however handled by yet another NCMA publication called TEK-15-4A: SRW Global Stability Analysis [4].

CONSTRUCTION DETAILS OF SRW

It is needless to underscore the fact that regardless of the time and money spent on developing, designing and manufacturing quality products and systems, the ultimate test is the product or system's performance in the field. It is more often the case, than not, the installation of products dictates how they will perform and be perceived by the public or owner. It is a fact that one such product in which performance is directly controlled and often measured by installation practices is Segmental Retaining Walls.

The basic construction steps are simple but should be understood thoroughly to ensure that the end-product comes up to the expectations of the end-users. These steps in the sequential order are described as follows with some caveats to be specifically noted and complied:

a. **Inspection:** The site should be thoroughly inspected. Unusual ground conditions should be noted and reported to the Designer.
b. **Excavation:** The site should be excavated to the lines and grades shown on the project grading plans. All surrounding structures should be protected from the effects of wall excavation.
c. **Foundation Preparation:** Following the excavation, the foundation soil should be examined to assure the actual soil strength meets or exceeds the assumed Design Bearing Strength. Soils not meeting the required value should be removed and replaced with infill soils as directed by the Designer. Foundation soil should also be proof-rolled and compacted to 95 % standard proctor density and inspected prior to placement of leveling pad materials.

d. **Leveling Pad Construction:** Leveling Pads should be placed as shown on the retaining wall plans with minimum thickness of 150 mm. The Leveling Pads should also extend laterally at least a distance of 150 mm from the Toe and Heel of the lower most SRW unit. Granular Leveling Pad material should be compacted to provide a firm, level bearing surface on which to place the first course of units. Well-graded sand can be used to smooth the top 6 to 12 mm of the Leveling Pad. Compaction should be with mechanical plate compactors to achieve 95 % of maximum standard Proctor density.

e. **SRW Unit Installation:** All SRW units should be installed at the proper elevation and orientation as shown on the drawings. The SRW units shall be installed in accordance with the manufacturer's recommendations. First course of SRW units should be placed on the Leveling Pad. The units should be leveled side-to-side, front-to-rear and with adjacent units, and aligned to ensure intimate contact with the Leveling Pad. The first course is the most important to ensure accurate and acceptable results. No gaps should be left between the front of adjacent units. All debris should be cleaned from top of units and the next course of units installed on top of the units below. Connection pins should be inserted through the pinholes of each course unit into receiving slots in lower course units. Pins should be fully seated in the pin slot below. Units should be pushed forward to remove any looseness in the unit-to-unit connection. Prior to placement of next course, the level and alignment of the units should be checked and corrected.

f. **Geo-synthetic Reinforcement Placement:** All geo-synthetic reinforcement should be installed at the proper elevation and orientation as shown on the drawings. The highest strength direction of the geo-synthetic must be perpendicular to the wall face. Also, geo-synthetic reinforcement layers should be one continuous piece for their entire embedment length. Splicing of the geo-synthetics in the design strength direction (perpendicular to the wall) is not permitted. Utmost care should be taken for the geo-synthetic reinforcements already laid. For instance, tracked construction equipment should not be allowed to operate directly on the geo-synthetic reinforcement. A minimum of 150 mm of backfill is required prior to operation of tracked vehicles over the geo-synthetic. Rubber-tired equipment, however, may pass over the geo-synthetic reinforcement at slow speed, which is at less than 8 kph. The geo-synthetic reinforcement should be free of wrinkles prior to placement of soil fill. The nominal tension should be applied to the reinforcement and secured in place with staples or by hand tensioning until reinforcement is covered by 150 mm of fill.

g. **Drainage Materials:** Drainage aggregate should be installed to the line, grades, and sections shown in the drawings. The aggregates should be placed to the minimum thickness shown on the drawings between and behind units. Drainage collection pipes should be installed to maintain gravity flow of water outside the reinforced soil zone. The drainage collection pipe should daylight into a storm sewer or along a slope, at an elevation lower than the lowest point of the pipe within the aggregate drain.

h. **Backfill Placement:** The reinforced backfill should be placed as per details in the drawings in the maximum compacted lift thickness of 250 mm and should be compacted to a minimum of 95 % of standard Proctor density, at a moisture content within 2 % of optimum. The backfill should be placed and spread in such a manner as to eliminate wrinkles or movement of the geo-synthetic reinforcement and the SRW units. Only hand-operated compaction equipment should be used within 1 m of the back of the wall units. Compaction within 1 m behind the wall units should be achieved by at least 3 passes of a lightweight mechanical tamper, plate or roller. At completion of wall construction, backfill should be placed level with final top of wall elevation. And, in any case care should be taken to ensure water runoff is all the time directed away from the wall face.

i. **SRW Caps:** SRW caps should be properly aligned and glued to underlying units with appropriate adhesive. Rigid adhesive or mortar is, however, not recommended. It is desirable that the caps overhang the top course by about 20-25 mm. Slight variations in overhang are, however, are acceptable to correct alignment at the top of the wall.

j. **Construction Adjacent to Completed Wall:** The construction activities adjacent to the completed wall should not be allowed to disturb the wall in any manner. Heavy paving or grading equipment should be kept a minimum of 1 m behind the back of the wall face. Equipment with wheel loads in excess of 7 KN/m² should not be operated within 3 m of the face of the retaining wall during construction adjacent to the wall [5].

STANDARDS AND THE FUTURE DESIGN CODE

Material property testing is essential and SRW units are no exception. Recently the focus of material property testing within the SRW industry has shifted from geo-synthetics to SRW units. It is reported that now owners, designers, and specifiers are increasingly requiring SRW unit durability and geo-synthetic interface testing on their projects in addition to unit physical properties. The increasing number of new SRW units entering market makes it imperative to understand the performance of these units from the

standpoint of material property, durability, and geo-synthetic interface.

Evaluation of physical and durability properties of SRW units is conducted in accordance with ASTM C1372 (Standard Specification for SRW units) and ASTM C1262 (Standard Test Method for Evaluating the freeze-thaw durability of manufactured Concrete Masonry), respectively. Furthermore, Geosynthetic-to-SRW unit interface capacity is tested according to ASTM D6638 (Standard Test Method for determining Connection Strength between geo-synthetic reinforcement and Segmental Concrete units) and NCMA SRWU-2, which is to do with Determination of Shear Strength between Segmental Concrete Units.

Although there are facilities available commercially elsewhere also, however, NCMA is cognizant of its responsibilities and as such has equipped the NCMA Research and Development Laboratory to conduct multiple testing programs for determining the performance characteristics of SRW units. NCMA is working in close cooperation with all the stakeholders in developing Specifications, Design & Manufacture of the systems through the Industry Design Guides, ASTM standards, specifications & test methods, and Manufacture Quality Control and Assurance plans. As a result we have seen remarkable developments in the industry of SRW. Recently ASTM approved a new Standard for testing the Shear Capacity of SRWs. Developed within ASTM D35 Geo-synthetics Committee, Standard Test Method for determining the Shear Strength between Segmental Concrete Units (modular concrete blocks) is used to determine the Shear Strength between two layers of SRW units. The test is carried out under conditions determined by the user that reproduce the facing system at full scale. The results of a series of tests are used to define a relationship between Shear Strength developed between Segmental Concrete units and normal load. This data is then utilized within SRW Design Software, such as NCMA's SRWall Ver 3.22, to evaluate the Facing Stability of conventional gravity and reinforced soil SRWs. This Standard is identified as ASTM D6916.

NCMA is also actively engaged with ANSI (American National Standards Institution) in development of a National Standard for SRWs. NCMA created a Committee comprised of Designers, Producers, Specifiers and Academics that was entrusted to oversee the development process and abide by ANSI guidelines. The NCMA Board of Directors supported Committee recommendations to review a new Draft Standard incorporating revised Internal Stability provisions. The members of the SRW design Manual and SRW-ANSI Task Groups have worked vigorously to develop a revised Standard that incorporates New Internal Design provisions. They presented to ANSI Standard Committee, responsible for seeking consensus to the Building Code Requirements for Design of SRW, with revised Internal Provisions based on a Trapezoidal Earth Pressure distribution in place of the classical Rectangular distribution. The proposed Distribution is supported by many years of research, including NCMA funded research conducted at the Royal Military College of Canada.

The Task Group members met and reviewed results from a parametric study evaluating the effects of the proposed new Internal Distribution on final geo-synthetic requirements. The study also considered the impact of geo-synthetic spacing, geometry of backfill above the top of Wall and Wall batter. Upon review of the Study results, it was determined that incorporating the revised Earth Pressure Distribution was founded on sound engineering principles and provided designs that appropriately model structural performance as seen in field instrumented structures. This finding is revolutionary indeed.

The new Draft Standard (Building Code Requirements for Design of Segmental Retaining Walls) is supposed to be balloted to the ANSI Standards Committee and finally the Draft for the development of the SRW model Building Code is due to be submitted to the International Code Council for final adoption as an ANSI recognized SRW Standard in the 2006 International Building Code [4,5,6].

CONCLUSIONS

SRW is a time-tested earth-retaining and earth-stabilizing technique, which has successfully made in-roads into the construction industry worldwide. The architects, structural & geotechnical engineers and the contractors now prefer this system over the conventional reinforced concrete cantilever retaining walls for many reasons; the economy being the over-riding factor. However, this system is little known in this part of the world. Hopefully with this article, SRW will be understood and introduced here also on large scale.

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IP TELEPHONY: AN INTRODUCTION

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ABSTRACT

IP telephony is a rapidly emerging technology for voice communication that has astonished both the data-communication and telecom industries. Technical developments over last few years have made the use of IP networks for telephony applications a reality. The objective of this paper is to provide the introduction to the technology, and describe the related protocols and the issues behind delivering an "appropriate" quality of service.

The paper reviews the IP telephony technology, covering its background, working, and various methods of its implementation. It then explores the pros and cons of this exciting technology and looks at what the future has to offer. It also examines the market trends and looks at what market researchers think about IP telephony. The paper also covers the architecture and protocols underlying IP telephony, and discusses the various signaling standards that make the technology possible. At the end, it covers the issues related to the voice quality and discusses how these may be dealt with.

INTRODUCTION

Little more than a decade ago Internet was not available to general public, interactive voice communications were only made by telephone at Public Switched Telephone Network (PSTN) and the data exchange was expensive for long distances. Then we saw appearing some interesting things: Personal Computers to large masses and Internet to general public. People begun to use PCs and Internet to communicate and to exchange data (images, sounds, documents) with new services like email, chat and discussion groups.

Availability of a telephone and access to a high quality public switched telephone network is considered to be essential in modern society. There is however, a Paradigm shift beginning to occur since more and more communications is in digital form and transported via packet networks such as IP, ATM and Frame Relay. Since data traffic is growing much faster than telephone traffic, there has been considerable interest in transporting voice over data networks.

Support for voice communications using the Internet Protocol (IP), usually called "*IP telephony*", has become especially attractive given the low cost, flat-rate pricing of the Internet. In fact, toll quality telephony over IP has now become one of the key steps leading to the convergence of the voice, video and data communications industries.

The first IP telephony product was introduced by Vocaltec in early 1995. In a very short period of time it has caught the world's attention. The technology has now improved to a point where conversations are easily possible and it continues to get better. Technology is improving so fast that it will not be long until phone-to-phone service on the Internet offers the same call quality as conventional phone service.

IP TELEPHONY

IP telephony (also known as *Internet telephony* or *Voice over IP*) is transport of voice calls over packet-switched IP-based data networks, no matter whether traditional telephony devices, multimedia PCs or dedicated terminals take part in the calls and no matter whether the calls are entirely or only partially transmitted over the IP network. This technology enables standard data packets to transmit multimedia information such as voice, fax or video over the Internet or a corporate intranet (IP-based private network) with suitable quality of service (QoS) and a much superior cost/benefit ratio. It draws on open standards and recommendations generated by international groups such as the Internet Engineering Task Force (IETF) and the International Telecommunication Union (ITU). All suppliers of Internet telephony products meet these standards.

When used only across an IP network, such as intranet or Local Area Network (LAN), it is generally known as

"*Voice over IP*" (VoIP). When the call originates and/or terminates in public switched telephone network, and the transport is Internet or Wide Area Network (WAN), it is generally called "*IP telephony*" or "*Internet telephony*."

IP telephony requires people, who want to talk to each other, to log onto a computer equipped with a microphone and speaker and establish a connection over the Internet. However, a user doesn't have to be online to reap the benefits of IP telephony – A user logged on to a computer may also make a call to a telephone. Even a telephone to telephone call can be made over the Internet. Whenever a telephone is used, the call must be transferred from the Internet to the local telephone system. The companies that provide Internet phone software also provide gateways through which these conversions occur. A fee for using the gateway is incurred by the user; these charges are very low compared to standard long-distance phone call charges. For example, a call to an ordinary telephone in United States from Saudi Arabia over the Internet could be as low as $.04/minute, as compared to $0.80/minute over telephone lines. Today, users can bypass long-distance carriers and their per-minute usage rates and run their voice traffic over the Internet for a flat monthly Internet-access fee.

Rapidly changing technology is making IP telephony a legitimate alternative for voice services over the Internet. And it doesn't stop with just voice over the Internet – other applications include fax over the Internet, call center integration, conference bridging and telecommuter access. These applications are all made possible over a single access line using TCP/IP architecture and the Internet.

PRINCIPLES OF IP TELEPHONY

To understand IP telephony, it's necessary to be familiar with the fundamental characteristics behind the Internet and how it compares to the Public Switched Telephone Network (PSTN). The most important of these characteristics is the data transport mode, also known as data connection type which is either a circuit switched or packet switched as explained below:

Circuit Switched Connection: A device using a circuit switched connection only connects when data is to be sent. The connection is dedicated exclusively to the sending and receiving nodes for the entire duration of the call. Because the two points are connected in both the directions, the connection is called a circuit. The connection is only present when you need it and, since bandwidth remains constant, you only pay for the duration of the connection. While connected on a circuit switched network you have exclusive use of the established connection and data can be sent continuously. This type of data transaction is typically routed through the PSTN. Although the circuit switched network provides a very reliable connection for voice transmissions, it makes very inefficient use of the available bandwidth.

Packet Switched Connection: While circuit switched connection is open and constant for the entire duration of the call, packet switched connection opens just long enough to send a small chunk of data, called a packet, from one system to another. A packet switched connection keeps you connected all the time but you only pay for the amount of data transferred. In this case, the data is divided into small packets and each packet contains a source and a destination address. Packets of data are sent from source to destination using the quickest route available. The network bandwidth is shared and multiple simultaneous users are allowed to access multiple locations across a network. This provides for much more efficient use of available bandwidth but can create problems for voice traffic, which is very sensitive to delay.

The PSTN is a circuit-switched network that has been optimized for real-time or synchronous voice communication with a guaranteed Quality of Service (QoS). The PSTN guarantees the QoS by dedicating a full-duplex 64Kbps circuit between the parties of a telephone conversation. Regardless of whether the parties are speaking or silent, they use full 64K dedicated circuit until the call ends. Much of this capacity is wasted during a normal telephone conversation, because while the line is working at full capacity, not all of each user's time is spent transferring data or talking.

On the other hand, IP networks are packet-switched networks that have historically been used for applications where a variable QoS is tolerable. Instead of keeping a circuit open constantly, IP networks send and receive data only as needed, a bit at a time, in data packets. By doing so, IP networks free up network resources, as well as the resources of the computers sending and receiving information. Since these do not dedicate a path between sender and receiver, these cannot guarantee QoS. There are, however, ways that can be used to get reasonable QoS on the IP networks.

The Basics of IP Voice Call

IP telephony technology uses packet-switching to minimize the amount of resources used in a telephone connection. The telephony application digitizes and compresses the analog voice signals. This data is then transmitted as a stream of packets over an IP network. IP network allows each packet to independently find the most efficient path to the intended destination, thereby best using the network resources at any given instant. At the destination, the packets are re-assembled back into their original order. The recipient IP telephony application then decompresses the packets and converts them back into the analog voice signal. The application insures proper reconstruction of the voice signals, compensating for echoes, jitter, and for dropped packets. The actual end-to-end process, however, may involve more steps as described below:

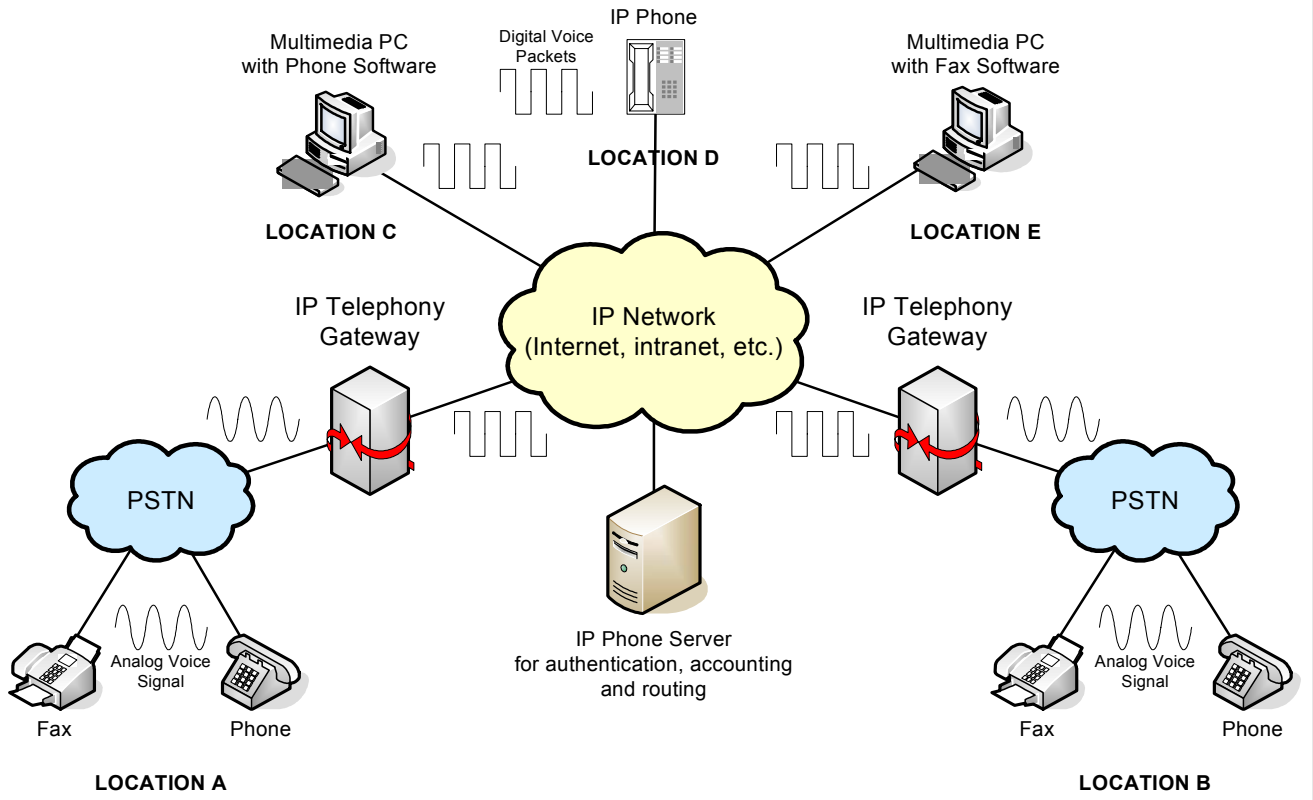

Figure 1: IP Telephony Infrastructure

A phone or fax call goes over the local PSTN to the nearest IP telephony gateway (*see* Figure 1). The gateway uses an Analog to Digital Converter (ADC) to encode the voice digitally and to compress/translate the signal into IP packets. It then moves the data onto IP network for transport to a gateway at the receiving end. The gateway at the receiving end decompresses the data and converts it back into analog voice signal using a Digital to Analog Converter (DAC). The gateway then hands over the voice signal to the PSTN network, which in turn passes it on to the phone or fax at the receiving end.

IP TELEPHONY SCENARIOS

The IP telephony usage scenarios, as shown in Figure 1, are commonly classified by the type of devices terminating an IP call. Because there may be either a PSTN device (e.g. telephone) or a data-oriented terminal (e.g. personal computer) on each side of a call, there are four generic classes as below:

PC-TO-PC

PC-to-PC communication can be provided for multimedia PCs (i.e. Personal Computers with a microphone, speaker and a sound card) operating over an IP-based network without connecting to the PSTN. PC applications (and IP-enabled telephones) can communicate using point-to-point or multipoint sessions. This set up requires that parties be equipped to talk at the time of the call.

This class is attractive especially for private users who already have an Internet access and a multimedia PC. Necessary software is available from several companies for free or at a very low cost. There is usually no charge for PC-to-PC calls, except for the cost of Internet access. The user doesn't even have to pay for long-distance calls. This pure-IP scenario can also take advantage of integration with other Internet services, such as instant messaging, video conferencing, etc.

PC-TO-TELEPHONE

The PC-to-Telephone method allows a user to call any ordinary telephone on a PSTN from his computer. In this case, a gateway converting the IP call into a PSTN call has to be used. The gateway is required to be located as near to the called party as possible, to minimize the price for the gateway-to-called party connection. The call is converted to a PSTN call at the gateway and is then sent over PSTN to its destination.

Like PC-to-PC calling, this scenario requires a software client. The software is usually free, but the caller may have to pay a small per-minute charge to a gateway operator. The cost charged by the operator is determined mainly by the cost of the call placed from the gateway to the called

party. This solution is commercially available from Net2Phone, PhoneServe and many other companies.

TELEPHONE-TO-PC

The Telephone-to-PC method allows a user to call from any ordinary telephone on a PSTN to a PC connected to the Internet. In this case, a gateway converting the PSTN call into an IP call has to be used, and the gateway is required to be located as near to the caller as possible. The call is converted to an IP call at the gateway. The voice data then "hops on" the Internet and finds the PC on the other end by using the unique IP address.

A few companies are providing special numbers or calling cards that allow a standard telephone user to initiate a call to a computer user. The caveat is that the computer user must have the vendor's software installed and running on his computer. This solution may require user to pay local call charges, in addition to small per-minute charge to a gateway operator.

TELEPHONE-TO-TELEPHONE

The Telephone-to-Telephone communication appears like a normal telephone to the caller but may actually consist of various forms of voice over packet network, all interconnected to the PSTN. In this scenario, a caller dials into a gateway using a regular telephone. The call is converted to an IP call at the gateway and the voice data "hops on" the Internet. At the end point the voice data hits another gateway and "hops off" the Internet. The voice data is converted back to PSTN format and sent over the PSTN to its destination.

This class is attractive for those who want to save on long-distance call and do not want to use PC. Since the call has to pass through two gateways – PSTN-to-Internet and Internet-to-PSTN, the cost is charged by both the gateway operators. In addition, the user may have to pay local call charges. This solution is commercially available from many companies, offering discounted rates for long distance IP telephony calls.

BENEFITS AND DRAWBACKS

BENEFITS

IP telephony could be applied to almost any voice communications requirement, ranging from a simple inter-office intercom to a complex multi-point teleconferencing environment. Listed below are the main benefits of using IP telephony:

- **Cost Reduction:** The first measure of success for IP telephony is the cost savings for long distance calls. Today flat rate long-distance pricing is available with the Internet and can result in considerable savings for both voice and fax. Large organizations with offices around the world save even more on long-distance calls by using local Internet gateways. IP telephony provides a competitive threat to providers of traditional telephone services that will clearly stimulate improvements in cost and function throughout the industry.
- **Simplification:** IP telephony enables a company to use a single communications medium rather than having to maintain separate systems for voice and data communications. An integrated infrastructure that supports all forms of communication allows more standardization and reduces the total equipment needs.
- **Flexibility:** IP telephony equipment has the flexibility to cater to a wide range of configurations and environments and the ability to blend traditional telephony with IP telephony. Hence, the quality of voice reproduction can be tailored according to the application. Customer calls may need to be of higher quality than internal corporate calls.
- **Network Efficiency:** The sharing of equipment and operations costs across both data and voice users can also improve network efficiency since a packet-switched IP network can handle more calls with the same transmission infrastructure than the PSTN can with its circuit switched TDM approach.
- **Integration:** Universal use of the IP protocols for both data and voice applications holds out the promise of reduced complexity and more flexibility. This provides an opportunity to share facilities such as directory services and security services, and eliminate points of failure.
- **Advanced Applications:** In addition to basic telephony and fax, the longer term benefits are expected to be derived from multimedia and point-of-service applications such as directory services that enable conference calls to be set up from Web-based directories, and wireless unified messaging, which will let users retrieve their voice and e-mail messages via their cellular phones. Combining voice and data features into new applications will also provide the greatest returns over the longer term.

DRAWBACKS

Listed below are the main issues and drawbacks of using IP telephony:

- **Voice Quality:** The voice quality of an IP telephone call over Internet is usually not quite as good as a conventional phone, but the low price compensates for it. The quality is often compared to that of a speakerphone; a little choppy at times, but generally

understandable. Calls on the public switched telephone network usually exhibit 50 to 70 ms delay. That latency increases substantially on the Internet, where it typically ranges to 500 ms.

- **Capacity:** One of the main parameters affecting the quality of service on the Internet is lost packets. It is a persistent problem, particularly with the increasing load of the Internet. This is mainly a function of network congestion. When traffic causes delays or out-of-order packets, some packets are dropped, causing breaks (silence) in the signal. Inadequate network access links, especially local ISP connections to the Internet backbone, are the major cause for bandwidth congestion.
- **Standards:** The major difficulty that IP Telephony technology is facing is the interoperability between IP telephony products. Hence, the users who want to make IP phone call have to have the same kind of software or IP telephony equipment.
- **Regulation:** Traditionally, telephone service has been heavily regulated. However, regulation of Internet telephony is still largely a question mark. Internet telephony has stirred fears from carriers throughout the globe, many of whom have reacted by seeking regulatory protection from the new technology. In most countries, governments or government- authorized entities retain the right for providing telephone service.

APPLICATIONS

IP telephony enables a whole new generation of applications which are impossible with other telephony architectures. Some examples of the applications that are likely to be useful are as follows:

1. **Advanced Intelligent Network Features:** Use advanced intelligent network (AIN) features such as Caller ID, voice mail, call waiting, pre-and-post paid calling cards, call blocking, and auto call-back in IP telephony.
2. **Voice Calls from Mobile Laptop PCs:** Call office or home, from hotel, airport, etc. using multimedia laptop PCs with wireless connection to Internet. This could be ideal for submitting or retrieving voice messages.
3. **Airlines Reservations:** Use a Java applet to visually display interactive voice response options rather than forcing users to wait through very long recorded instructions and go through multi-level menus requiring the use of a telephone keypad.
4. **Internet-aware Telephones:** Use enhanced ordinary telephone (wired or wireless) as an Internet access device as well as for normal telephony. Directory services, for example, could be accessed over the Internet by submitting a name and receiving a voice (or text) reply.
5. **Voice Annotated Ddocuments:** Send voice messages and voice annotated documents to integrated voice/data mailboxes. Voice annotated documents and multimedia files can easily become standard within office suites in the near future.
6. **Internet Call Center Access:** Access customer service agents online over an Internet call center.
7. **Virtual Call Centers:** Support the integrated voice and data requirements of call center agents working from their homes.
8. **Live Auction Websites:** Create live audio auction websites for excess inventory. Use Java applets on the phone to manage the bidding process and to track who “raised a hand” to bid first, etc.
9. **Presence and Instant Messaging:** Use instant messenger service to determine when geographically distributed colleagues are available for a quick conference call with a customer.
10. **Electronic Business Cards:** Send an enriched electronic virtual business card (vCard) including photo and audio file automatically with every call as caller ID information (or selectively during the middle of call).
11. **Integrated Voice and Data Information:** Integrate voice and data information collected during a call with sales force automation applications.
12. **Personalized Music On-hold:** Play personalized announcements or music from a favorite MP3 recording or Internet radio station while callers are on hold.

MARKET TRENDS

IP telephony is becoming a key driver in the evolution of voice communications. While it is currently a small fraction of telecommunication market, it is growing quickly. Here is a selection of what market researchers think about IP telephony:

- According to IDC's January 2003 forecast, worldwide sales of IP telephony equipment will see substantial growth between 2004 and 2007, increasing by 48% in 2004 and topping $4.9 billion by year's end. Equipment sales will continue to grow by more than 50% in 2005 and 2006, to reach $11.4 billion in 2006, and $15.1 billion in 2007 (Figure 2).
- Businesses spent an estimated $2.0 billion on IP-capable telephone systems in North America in

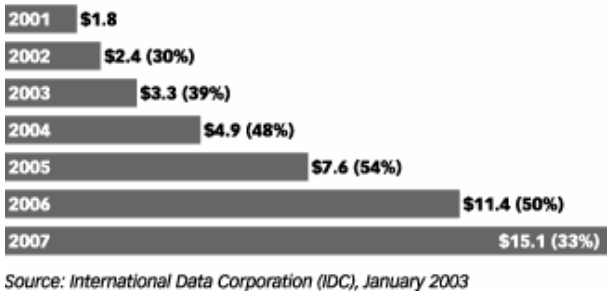

Figure 2: Worldwide IP Telephony Equipment Revenues, 2001-2007 (in Billions & % Growth)

2003, according to Gartner Dataquest, which also predicts that enterprises spending on IP phone systems will more than double during four years, to reach $4.2 billion in 2007.

- According to Gartner, the IP telephone systems accounted for just 1.4% of total business telephony equipment sales in 1999. However, in 2003 IP telephony equipment increased its market share to 56% of all sales, and by 2007, it is expected to account for 97% of all business telephony sales.
- The IP PBX market is expected to grow to $3.9 billion in revenue by 2005, representing nearly 20% of all traditional PBX sales. (Synergy Research, February 2002)
- By 2005, analysts predict 34% of all telephone calls made worldwide will be carried over the Internet, accounting for over 90 billion minutes of telephone communication.
- Wholesale and retail VoIP traffic volume exceeded 6 billion and 15 billion minutes in 2000. VoIP will account for approximately 75% of world voice services by 2007. (Frost & Sullivan, May 2001)
- VoIP will account for approximately 75% of world voice services by 2007. (Frost & Sullivan, March 2002)
- By 2008, wholesale VoIP traffic in the Europe, Middle East and Asia (EMEA) region could reach 57 billion minutes. About 1,771 billion minutes of retail voice traffic originating in EMEA will have a VoIP component in some portion of the route. (Frost and Sullivan, May 2002)
- According to a study conducted by Insight Research Corporation, from a mere $13 billion in 2002, voice over packet (VoIP)-based services will grow to nearly $197 billion by 2007. Also, VoIP services will grow at a compounded rate of over 72 percent over the period 2002-2007, making packet voice services one of the fastest-growing segments in the telecommunications industry (Press Release – "Phone Industry Survival hinges on Explosive Growth of VoIP" – October 28, 2002)
- Enterprises will migrate their voice systems from traditional networks to data networks at a rate that will create a $16.5 billion dollar IP-PBX market worldwide by 2006. (Allied Business Intelligence.)
- 90% of enterprises with multiple locations will start switching to IP systems for voice over next 5 years. (Phillips Group, via Aspect, June 2001)
- The European IP Virtual Private Network (VPN) services market to grow from 1.74 billion at the end of 2002 to 3.58 billion by 2005, when almost 40% of the identified potentials within the European market will have implemented an IP VPN solution. (Frost and Sullivan, January 2003)

IP TELEPHONY PROTOCOL ARCHITECTURE

Like any conversation between two computing devices, IP telephony requires an agreed upon set of rules, called "*protocol*". Figure 3 shows an architectural diagram of the protocols that are used to govern IP calls. These protocols follow a layered hierarchy which can be compared with the Open Systems Interconnect reference model (OSI 7-layer model), developed by the International Standards Organization (ISO). Although the IP telephony model doesn't exactly match OSI structure, it is useful for discussion.

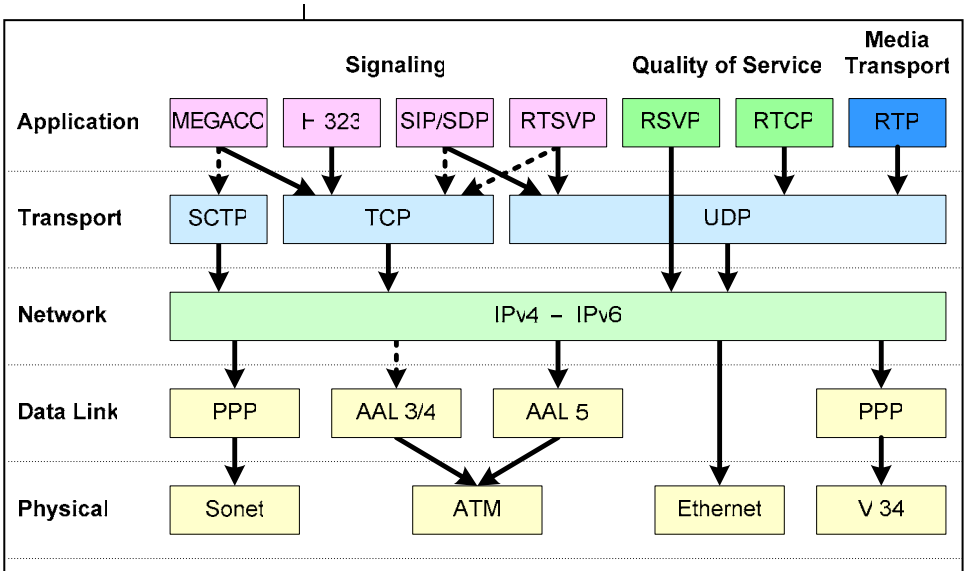

Figure 3: IP Telephony Protocol Suite in Relation to the ISO Model

Breaking a system into defined layers can make that system more manageable and flexible. A layer defines a specific data communication function that may be performed by any number of protocols. Each layer has its job, and does not need a detailed understanding of the layers around it. For example, IP datagram (or packet) can be transported across a variety of physical layer systems including serial lines, Ethernet and ATM. The data is passed down the stack when it is being sent to the network and up the stack when it is being received from the network.

The physical and link layer protocols provide the means for the system to deliver data to the other devices on a directly attached network. Unlike higher-level protocols, these protocols must know the details of the underlying network (its packet structure, addressing, etc.) to correctly format the data being transmitted to comply with the network constraints. The physical layer protocol is for the most part irrelevant to IP and need not be the same for first link and final link of a VoIP call.

The major protocols involved in IP telephony, started at the Network layer are discussed in the following sections:

INTERNET PROTOCOL (IP)

The Internet Protocol (IP) is a network layer protocol and it is the heart of the IP telephony. It provides the basic packet delivery service on which IP telephony networks are built. All protocols, in the layers above and below IP, use the Internet Protocol to deliver data.

IP is responsible for defining the datagram (or packet) and moving data between link layer and transport layer. It is also responsible for routing datagrams to remote hosts and performing fragmentation and re-assembly of the datagrams. IP is a connectionless protocol, that is, it does not establish an end-to-end connection through a network before transmitting data. IP relies on protocols in other layers to establish the connection if they require connection-oriented service.

IP makes no guarantees concerning reliability, flow control, error detection or error correction. This means that the packets could arrive at the destination computer out of sequence, with errors or may not arrive at all. IP just transports the data to a higher layer and relies on protocols in the other layers to provide error detection and error correction.

TRANSMISSION CONTROL PROTOCOL (TCP)

The Transmission Control Protocol (TCP) is a transport layer protocol and is responsible for delivering data received from IP to the correct application. The application that the data is bound for is identified by a 16-bit number called the port number (for example, the HTTP application is usually associated with port 80). TCP uses 16-bit source-port and destination-port numbers in segment header, to deliver data to the correct applications process.

TCP is a connection-oriented protocol. It establishes a logical end-to-end connection between the two communicating hosts before transmitting data. TCP also provides a reliable data delivery across the network using a mechanism called Positive Acknowledgment with Re-transmission (PAR). Simply stated, a system using PAR sends the data again, unless it hears from the remote system that the data arrived okay.

TCP also handles sequencing and error detection, ensuring that a reliable stream of data is received by the destination application. It views the data it sends as a continuous stream of bytes, not as independent packets. Therefore, TCP takes care to maintain the sequence in which bytes are sent and received.

Although the TCP works smoothly with data – any packet not delivered is simply re-transmitted, it does not work well with real-time voice and video applications. It is because any word received out of sequence within the structure of a sentence will result in a garbled message.

USER DATAGRAM PROTOCOL (UDP)

User Datagram Protocol (UDP) is also a transport layer protocol and is responsible for the transmission of information between the correct applications on the host computers. The UDP uses 16-bit source-port and destination-port numbers in the message header, to deliver data to the correct applications process.

Like IP, UDP is a connectionless protocol as it does not establish an end-to-end connection between two communicating hosts before transmitting data. It routes data to the correct destination port, but does not attempt to perform any sequencing, or to ensure data reliability. The UDP gives application programs direct access to a datagram delivery service, like the delivery service that IP provides. This allows applications to exchange messages over the network with a minimum of protocol overhead.

For voice applications, UDP ensures that the information is received in correct sequence, reliably and with predictable delay characteristics. UDP also performs certain functions that TCP cannot perform. Hence, it is commonly used for IP telephony.

REAL-TIME TRANSPORT PROTOCOL (RTP)

Real time applications, such as voice and video, require mechanisms to be in place to ensure that a stream of data can be reconstructed accurately. In IP networks, the connection-oriented TCP protocol guarantees an error-free transmission in the right order but it is not appropriate for real-time applications. For instance, with video, if a packet arrives late, it loses its meaning and may not be inserted correctly in the clip being played. For this reason, UDP is used for voice and video transmission.

Jitter is the variation in delay times experienced by the individual packets making up the data stream. In order to

reduce the effects of jitter, data must be buffered at the receiving end of the link so that it can be played out at a constant rate. However, the UDP has no control over the order in which packets arrive at the destination or how long it takes them to get there. Both of these are very important to overall voice and video quality. Real-time transport protocol (RTP) solves the problem by enabling the receiver to put the packets back into the correct order and not wait too long for packets that have either lost their way or are taking too long to arrive. RTP is really just the underlying transport plane, and the other protocols use it to successfully transport voice and video packets.

RTP is designed to provide end-to-end network transport functions for applications transmitting real-time data, such as voice and video, over IP networks. It carries data source and payload type information, and is itself carried inside of UDP. RTP provides the sequence number and time stamp information needed to assemble a real time data stream from packets. However, RTP does not have any mechanisms for ensuring the on-time delivery of traffic signals or for recovering lost packets. Therefore, RTP does not reduce the overall delay of the real time information. Nor does it make any guarantees concerning quality of service.

RTP CONTROL PROTOCOL (RTCP)

The RTP Control Protocol is the counterpart of RTP that provides control services. The RTCP monitors the QoS and conveys information about the participants in an ongoing session. It provides feedback on total performance and quality so that modifications can be made. Other RTCP functions include carrying a transport-level identifier for an RTP source which is used by receivers to synchronize audio and video.

RESOURCE RESERVATION PROTOCOL (RSVP)

The Resource Reservation Protocol is a signaling protocol that supports the reservation of resources across an IP network. It manages quality of service by requesting a certain amount of bandwidth and latency in every network hop that supports it. Applications running on IP end systems can use RSVP to indicate to other nodes the nature (bandwidth, jitter, maximum burst, and so forth) of the packet streams they want to receive. The RSVP depends on IPv6.

IP TELEPHONY SIGNALING PROTOCOLS

Several standards are available for building IP telephony solutions. These include H.323, Session Initiation Protocol (SIP), Media Gateway Control Protocol (MGCP) and Media Gateway Control (Megaco). A high-level comparison of these protocols is included in Table 1.

Of the protocols listed in Table 1, only SIP and H.323 are peer-to-peer protocols. MGCP and Megaco represent the old centralized model and suffer from this model's limitations. Thus, the real choice for a protocol with Web-like benefits comes down to one of the peer-to-peer protocols – H.323 or SIP.

The H.323 and SIP are the two major protocols that are used by VoIP technology to define ways for devices (telephones, computers, etc.) on the data network to communicate with each other. H.323 is a comprehensive and very complex protocol. It provides specifications for real-time, interactive videoconferencing, data sharing and IP telephony. The Session Initiation Protocol (SIP) emerged as an alternative to H.323. It is a much simpler, more streamlined protocol developed specifically for IP telephony. It is smaller and more efficient than H.323 and takes advantage of existing protocols to handle certain parts of the process.

Both of these protocols do essentially the same things; these provide a way for the caller to find the called party (call construction), allow each party to send streams of audio data to the other party, and provide a way for either party to end the call (call tear-down). Both of these protocols also include specifications for audio (and video)

Table1: Comparison of IP Telephony Protocols

	H.323	SIP	MGCP	Megaco/H.248
Standardization	ITU-T	IETF	IETF	IETF and ITU-T
Architectural model	Peer-to-peer	Peer-to-peer	Master/ slave	Master/ slave
Media types	Voice, video, limited data	Voice, video, data	Voice	Voice, video
Call control	Gatekeeper	Proxy/Redirect Server	MGC	MGC
Endpoints	Gateway, terminal	User agent	Media gateway	Media gateway
Signaling transport	TCP or UDP	TCP or UDP	UDP	TCP and UDP
Network scope	Intranet, Extranet, Internet	Intra-, Extra-, Internet	Intranet only	Intranet only
Extensibility	Low	High	Medium	Medium
Scalability	Medium	High	Low	Low
Ease of deployment	Low	High	Medium	Medium
Standardization	ITU-T	IETF	IETF	IETF and ITU-T

codecs (coder-decoder) to convert audio signal into a compressed digital form for transmission and back into an uncompressed audio signal for replay. These protocols are discussed in detail in the following sections:

H.323

The H.323 is an umbrella recommendation from the Telecommunication Standardization Sector of the International Telecommunications Union (ITU-T) that specifies the components, protocols and procedures that provide multimedia communication services (real-time voice, video, chat, whiteboard, file sharing, etc.) over packet–based networks, including IP. By conforming to H.323 standards, multimedia products and applications from different vendors can interoperate across IP based networks, including the Internet. H.323 is part of a family of ITU-T recommendations called H.32x that provides multimedia communication services over a variety of networks.

H.323 covers both protected and unprotected connections. Control and data information requires a protected transmission to prevent packets from being lost or not received in the right order. In IP-based networks, TCP protocol guarantees an error-free transmission in the right order but causes delays and has a lower throughput. Therefore, unprotected connections are used for audio and video transmissions, which are more efficient.

The H.323 standard's mandatory components are transmission of audio, connection control according to Q.931, communication with the gatekeeper over the RAS protocol, and use of the H.245 signaling protocol; the rest of the text, including coverage of the ability to transmit video and data, is optional. Although H.323 uses TCP to carry the signaling channels, the real-time media streams are transported on RTP/RTCP (discussed earlier). RTP carries the actual media and RTCP carries status and control information.

Being the first widely available VoIP protocol, H.323 enjoyed a head start as developers implemented it as toll-bypass systems as well as PC-to-phone and video-conferencing applications. The best-known H.323 application was Microsoft NetMeeting.

History

The Version 1 of the H.323 recommendation was accepted in October 1996. It was heavily weighted towards multimedia communications in LAN environment and does not provide guaranteed quality of service. With the development of VoIP, new requirements emerged, such as providing communication between a PC–based phone and a phone on a traditional Switched Circuit Network (SCN). Such requirements forced the need for a standard for IP telephony. Version 2 of H.323, packet-based multimedia communications systems, was defined to accommodate these additional requirements and was accepted in January 1998.

H.323 Version 3, approved on September 30, 1999, and Version 4, approved on November 17, 2000, only makes modest improvements to the Version 2 Recommendation, introducing only a few new powerful features to the base document. The last Version 5 was approved at the end of July 2003. Unlike previous revisions of the recommendation, Version 5 aimed to maintain stability in the protocol by introducing only modest additions to the base protocol, rather than introducing sweeping changes as was the case in prior revisions.

H.323 Architecture Components

The H.323 standard specifies a number of components (entities), which, when networked together, provide the point-to-point and point-to-multipoint multimedia-communication services. Some components are mandatory, while others are optional. The four most important components are listed below:

Terminal: An H.323 terminal is an endpoint on a network which provides two-way communications with another terminal, gateway or a Multipoint Control Unit (MCU). An H.323 terminal can either be a personal computer or a stand-alone device such as IP telephone running H.323 and the multimedia applications. It supports audio communications and can optionally support video or data communications.

Gateway: An H.323 gateway provides connectivity between an H.323 network and a non–H.323 network. For example, it may route Voice over IP (VoIP) calls from an H323 terminal to the public switched telephone network (PSTN). This connectivity of dissimilar networks is achieved by translating protocols for call setup and release, converting media formats between different networks, and transferring information between the networks connected by the gateway. A gateway is not required, however, for communication between two terminals on an H.323 network.

Gatekeeper: A gatekeeper provides basic admission control onto a network by allowing or refusing communications between other H.323 entities within its zone of control. They also provide call-control services for H.323 endpoints, such as address translation (to use name instead of IP address), authentication, accounting and bandwidth management. Gatekeepers in H.323 networks are optional. If they are present in a network, however, terminals and gateways must use their services.

Multipoint Control Unit (MCU): An MCU provide services that allow three or more endpoints to take part in a conference call. All terminals participating in the conference establish a connection with the MCU. The MCU manages conference resources, negotiates between terminals for the purpose of determining the audio or video coder/decoder (codec) to use, and may handle the media stream.

H.323 Protocols

H.323 is a comprehensive and very complicated protocol. As shown in Table 2, it ties together a number of existing recommendations defined by International Telecommunications Union (ITU) and Internet Engineering Task Force (IETF). These protocols, together with some other recommendations, provide specifications for a range of communication including real-time voice, video and data transmission (*see* Figure 4). An overview of these protocols is given below:

Table 2: H.323 Protocol Suite

Video	Audio	Data	Transport
H.261	G.711	T.122	H.225
H.263	G.722	T.124	H.235
	G.723.1	T.125	H.245
	G.728	T.126	H.450.1
	G.729	T.127	H.450.2
			H.450.3
			RTP
			X.224.0

G.7xx Audio Codecs: The recommendations G.711 (audio coding at 64 kbps), G.722 (64, 56, and 48 kbps), G.723.1 (5.3 and 6.3 kbps), G.728 (16 kbps), and G.729 (8 kbps) define the way in which analogue audio signals are encoded into compressed digital form for transmission, and decoded back into an uncompressed audio signal for replay. Because audio is the minimum service provided by the H.323 standard, all H.323 terminals must have at least one audio CODEC support.

H.26x Video Codecs: The recommendations H.261 and H.263 define methods for encoding analog video into digital form for transmission and decoding back into analog video code for replay. Because H.323 specifies support of video as optional, the support of video codec is optional as well.

H.225 Call Signaling: H.225 call signaling is used to set up connections between H.323 endpoints (terminals and gateways), over which the real-time data can be transported. Call signaling involves the exchange of H.225 protocol messages over a reliable call-signaling channel. For example, H.225 protocol messages are carried over TCP in an IP–based H.323 network. The call-signaling channel is opened between two H.323 endpoints or between an endpoint and the gatekeeper.

H.225 RAS: H.225 registration, admission, and status (RAS) is the protocol between endpoints (terminals and gateways) and gatekeepers. The RAS is used to perform registration, admission control, bandwidth changes, status, and disengage procedures between endpoints and gatekeepers. A RAS channel is used to exchange RAS messages.

H.245 Control Signaling: H.245 control signaling is used to exchange end-to-end control messages governing the operation of the H.323 endpoint. The messages carried include messages to exchange capabilities of terminals and to open and close logical channels. The H.245 control messages are carried over H.245 control channels.

Q.931: Q.931 is a call signaling protocol and is used for establishing H.323 calls. H.225 call control messages are embedded within the user-to-user elements of Q.931 messages to provide additional information not available in Q.931 such as IP address information.

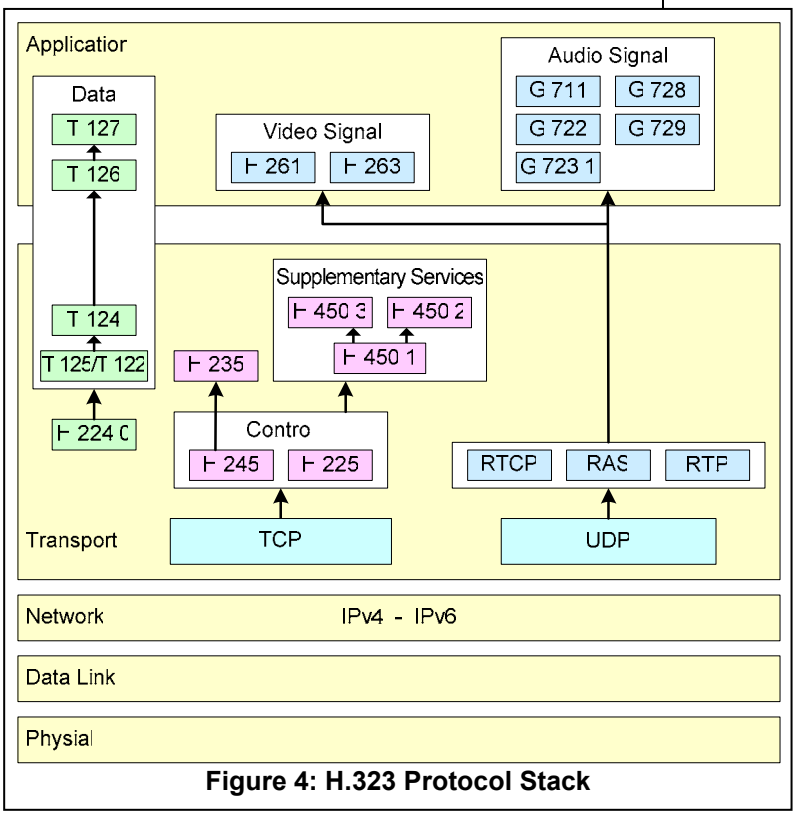

Figure 4: H.323 Protocol Stack

RTP: Real-Time Transport Protocol (RTP) provides end-to-end network transport functions for applications transmitting real-time data over IP networks. It provides services such as payload type identification, sequence numbering, time-stamping, and delivery monitoring to real-time applications. RTP can also be used with other transport protocols. RTP is discussed in detail in an earlier section.

RTCP: Real-time Transport Control Protocol (RTCP) is the counterpart of RTP that provides control services. The primary function of RTCP is to provide feedback on the quality of the media received using RTP. RTCP is discussed in detail in an earlier section.

SESSION INITIATION PROTOCOL (SIP)

The Session Initiation Protocol (SIP) emerged as an alternative to H.323, under the auspices of the Internet Engineering Task Force (IETF). SIP is a much more streamlined and powerful protocol, developed specifically for IP telephony. Smaller and more efficient than H.323, SIP takes advantage of existing protocols to handle certain parts of the communication process. For example, Media Gateway Control Protocol (MGCP) is used by SIP to establish a gateway connecting to the PSTN system.

Since H.323 was originally designed for video conferencing over private, high speed LAN, it assumes details like authorization and user identification. H.323 also provides all these extra services which are not usually considered useful for a simple phone call. SIP, however, was designed from the beginning for multimedia sessions and conferences over Internet and wide area network (WAN). Because of these differences in their design objectives, SIP offers numerous compelling advantages in the areas of extensibility, scalability, and ease of deployment over H.323.

SIP is transport layer independent. It can run over any datagram or stream protocol such as UDP, TCP, ATM, etc. It makes use of the Session Description Protocol (SDP) for specification of the session parameters. The audio or video data streams are transported using RTP over UDP. SIP may use any IANA registered codec while H.323 requires ITU-T defined standard only.

SIP enables new services and applications not possible with H.323 and other IP telephony protocols. For example, SIP uses a simple text-based encapsulation (based on the Internet standard MIME) which enables it to transmit data and application programs with the voice call, making it easy to send files, photos, and MP3 encoded information during a call. It also enables developers to push the intelligence to the edge of the networks, implement a distributed architecture, and create advanced features.

Being peer-to-peer protocols, both SIP and H.323 eliminate the need for central servers to control everything. However, within peer-to-peer protocols, SIP is a much more efficient and less complex protocol, therefore, more scalable than H.323. A high level SIP protocol stack is shown in Figure 5.

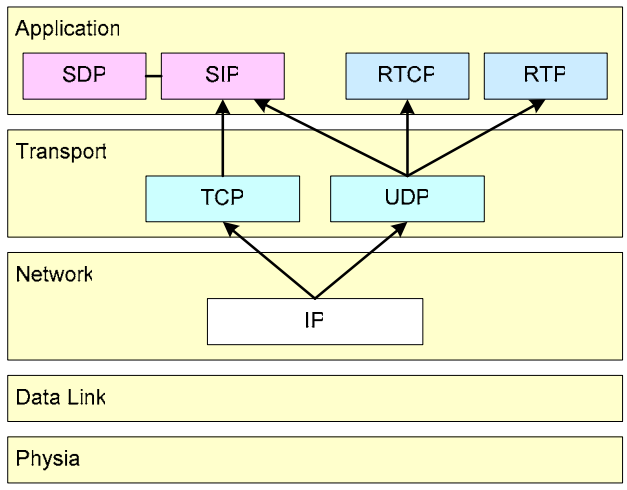

Figure 5: SIP Protocol Stack

SIP Concepts

Session: Session is the basic building block in SIP. A SIP session is a multimedia session consisting of a set of multimedia senders and receivers, and the data streams flowing from senders to receivers. All calls and conferences are established by setting up sessions among users.

Conference: A conference is a multimedia session, identified by a common session description. A conference can have zero or more members and includes the cases of a multicast conference, a full-mesh conference and a two-party "phone call", as well as combinations of these. Any number of calls can be used to create a conference.

Call: A call consists of all participants in a conference invited by a common source. A SIP call is identified by a globally unique call-ID.

SIP Architecture Components

SIP specification defines a number of components that are required to develop a SIP-based network. In many implementations, some of these components are combined into the same software modules.

SIP User Agents

A SIP user agent (UA) is a program that runs on a SIP device such as IP phones and gateways. It contains a client function and a server function.

The user agent client (UAC) initiates SIP requests such as initiating a call. It is the only entity on a SIP-based network that is permitted to create an original request. The UAC is also known as the calling user agent.

A user agent server (UAS) is one of many server types that receives SIP requests such as an incoming call and sends back responses to those requests. A UAS is also known as the called user agent. Normally, user agents are discussed without any distinction made between their UAC and UAS components.

SIP servers

The SIP servers are distinguished by their roles played by centralized hosts on a distributed network. There are four types of SIP servers that can be implemented in a user agent (UA). These are as follows:

Location Server: A location server is used to obtain information about called party's possible location. A location is the IP address of the domain where a user is located. To locate a user, the name of the user is sent to the location server and the location server returns zero or multiple locations (IP addresses of domains) where a called party may be found.

Proxy Server: A proxy server is an intermediary program that acts as both a server and a client for the purpose of making requests on behalf of other clients. Requests are

serviced internally by a proxy server or transferred to other servers.

Redirect Server: A redirect server is a server that accepts a SIP request, maps the address into zero or more new addresses and returns these addresses to the client. Unlike a Proxy, it cannot accept calls but can generate SIP responses that instruct the UAC to contact another SIP entity.

Registrar Server: A registrar server is a server that accepts REGISTER requests. A client uses the REGISTER request to let a proxy or redirect server know the location where the client can be reached. It provides a means whereby users can register their locations with a SIP server dynamically.

MEDIA GATEWAY CONTROL PROTOCOL (MGCP)

Media Gateway Control Protocol (MGCP), endorsed by the Internet Engineering Task Force (IETF), is a protocol for handling the signaling and session management needed during a multimedia conference. It is used for controlling telephony gateways from external call control elements called media gateway controllers or call agents. A telephony gateway is a network element that provides conversion between the audio signals carried on circuit-switched network (such as PSTN) and data packets carried over packet-switched networks (such as Internet).

MGCP assumes signaling control intelligence outside the gateways, in a media gateway controller (MGC). MGCP makes it possible for the MGC to determine the location of each communication endpoint and its media capabilities so that a level of service can be chosen that will be possible for all participants. MGCP can be used to set up, maintain, and terminate calls between multiple endpoints.

The MGCP specifies a protocol at the Application layer level that uses a master-slave model, where the gateways are expected to execute commands sent by the media gateway controllers. Two Media Gateway Controllers use RTP to talk to one another and successfully transport voice packets.

MGCP is well suited for centralized systems that work with dumb endpoints, such as analog phones. The most celebrated use of MGCP is for high-capacity gateways designed to work with traditional telecom equipment.

MEGACO / H.248

Megaco/H.248 is the Media Gateway Control Protocol defined jointly by IETF and ITU-T for use in distributed switching environments. The standard is endorsed by the IETF as Megaco and by the ITU-T as Recommendation H.248.

The Megaco/H.248 protocol was developed from the Media Gateway Control Protocol (MGCP) – it refers to an enhanced version of MGCP. Megaco/H.248 provides broadly equivalent functionality and has a very similar structure. The later Megaco/H.248 version supports more ports per gateway, as well as multiple gateways, and support for Time-Division Multiplexing (TDM) and Asynchronous Transfer Mode (ATM) communication.

VOICE QUALITY CHALLENGES AND SOLUTIONS

Traditional telephony networks are built to provide an optimal service for time-sensitive voice applications; these provide constant but low bandwidth services. However, IP networks were built to support non-real-time applications such as email, file transfer and web information. These networks send and receive data only as needed, in data packets. Because each packet is individually routed across the network, this makes packet-switching networks inherently less efficient in dealing with voice traffic and poses a number of challenges to a quality voice transmission.

CHALLENGES

It has been found that there are three factors that can profoundly impact the quality of the service. These are:

Delay (Latency): Delay in a voice network is the time required for a voice signal to traverse the network. Two problems that results from high end-to-end delay are "*echo*" and "*talker-overlap*". Echo becomes annoying when the delay is more than 50 ms. It is perceived as a significant quality problem. Talker-overlap can cause the receiver to start to talk before the sender is finished. It becomes unacceptable if the one-way delay becomes greater than 450 ms. Delay is inherent in data networks where it has no real impact, but with voice it is necessary that Quality of Service (QoS) features are implemented right across the IP network. Sources of delay in a packet voice call include the collection of voice samples (accumulation delay), encoding/decoding and packetizing time, jitter buffer delays, and network transit delay. IP telephony gateways and terminals also contribute significantly to delay.

Jitter (Delay Variability): Jitter is the variation in inter-packet arrival time. In IP networks, packets that belong to the same transmission do not always arrive with the same amount of delay. This variation in delay is referred to as "*jitter*." The jitter causes gaps in the speech pattern; as a result, voice transmissions may sound unnatural.

Packet Loss: IP networks do not provide guaranteed delivery of the packets. The packets can be dropped under peak loads and during periods of congestion (caused, for example, by link failures or inadequate capacity). For non-real-time applications, such as email and file transfers, packet loss is not critical – the protocol allows

retransmission to recover dropped packages. However, real-time voice data has to arrive within a certain time window to be useful to reconstruct the voice signal.

SOLUTIONS

In order to deal with these issues and provide a voice service with a reasonable measure of quality, there are many techniques that are employed to deal with network congestion and delay. These techniques include the following:

Prioritization: Prioritization is a method of guaranteeing throughput for certain traffic on the network. This can ensure that voice traffic on a data network is given high priority. This prioritization can be based on location, protocol or application type. RSVP is designed to ensure this QoS.

Fragmentation: Fragmentation divides the packets into smaller fragments so that their priority can be ensured. This can help reduce the overall delay of voice delivery. However, this can create extra overhead because of the large size of IP headers (20 bytes). So although necessary, fragmentation alone cannot ensure the reliable delivery of real-time voice applications.

Jitter Buffering: Jitter buffering is a technique that allows packets to be collected into a buffer and held there long enough for the slower packets to arrive so that they can all be played in proper sequence. Although this can remove packet delay, this creates additional overall delay. The best compromise is to fit jitter buffer in the network's differential delay. This will provide the necessary balance between the packet delay and the overall delay.

Silence Suppression: Silence suppression is a technique that is used to suppress the transmission of silence. These techniques take advantage of half-duplex nature of human conversation (one person listens while the other talks) by detecting when there is a gap and then suppresses the transmission of these silences. This can amount to 50-60% of the time of a call, resulting in considerable bandwidth conservation. However, because these silences are necessary for the conversation to sound natural, the receiving device must interpret the lack of packets and re-insert the silent spots, called *comfort-noise*, into the output.

Echo Cancellation: Echo cancellation is used to cancel the echo caused by end-to-end delay of a voice transmission. Echo cancellers monitor speech from the far end that passes through its receive-path and use this information to compute an estimate of the echo that is then subtracted from its send-path. ITU protocols G.165 and G.168 define the performance requirements that are currently required for echo cancellers.

Interpolation of Speech: Interpolation of speech is an approach used to compensate for packet loss. If certain voice packets are delayed beyond a specific threshold, IP telephony software interpolates by re-playing the last packet, and sending of redundant information. In order to help ensure a quality voice conversation, packet losses greater than 10% are not tolerable. For packet losses under 10%, interpolation can help maintain a continuous flow of voice with minimal distraction to the quality.

Speech Codecs: A speech codec transforms analog voice into digital bit-streams, and vice versa. In addition, some speech codecs also use compression techniques to reduce the transmission bandwidth required. Most PSTN networks use ITU-T G.711 recommendation that encodes the speech at 64 kbps. Current ITU-T recommendations include codecs that compress to as low as 5.3 kbps, although quality at this bit rate is well below that of the highest quality G.711. Essentially, compression is a balancing act between voice quality, local computation power, delay, and network bandwidth required. In general, the lower the bit rate, the lower the quality perceived by the listener. However, more modern codec designs are driving up the quality for a given bit rate. The more recent, though computationally intensive codecs, GSMEFR at 12.2 kbps and G.728 at 16 kbps, are comparable to the low-complexity G.726 codec that offers good performance only at 32 kbps or above.

In order for different manufacturers to implement these various techniques and maintain interoperability, the standards like H.323, SGCP, SAP, SIP, RTSP and SDP have been recommended and approved.

CONCLUSION

Data traffic has traditionally been forced to fit onto the voice network. The Internet has created an opportunity to reverse this strategy – voice, video, fax and other multimedia can now be carried over IP networks.

IP telephony users enjoy free long distance phone calls, coupled with numerous additional features. Both traditional telephone features, such as call-waiting and voice mail are included, as well as non-traditional features, such as group chats and text-based document sharing. Although the quality isn't as good as conventional phone calls, the discounted prices make up for it.

Although the price of IP call is now negligible, the phone companies will be likely to object to the free long distance service offered by the Internet and may raise the price of local phone calls in response. It remains to be seen whether or not IP telephone calls will continue to be such a good bargain to the average user, since the pricing for voice traffic is now undergoing change.

Voice communications will certainly remain a basic form of interaction for all of us. The public switched telephone network simply cannot be replaced, or even dramatically changed, in the short term. The immediate goal for IP telephony developers is to reproduce existing telephone capabilities at a significantly lower "*total cost*" and to offer a technically competitive alternative to the PSTN.

As data traffic continues to increase and surpass that of voice traffic, the convergence and integration of these technologies will not only continue to improve, but will also pave the way for a truly unified and seamless means of communication. The economics of placing all traffic (voice, video and data) over an IP network will pull companies in this direction, simply because IP will act as a unifying agent, regardless of the underlying architecture (e.g., leased lines, frame relay, or ATM) of an organization's network.

The market for IP telephony products is established and is beginning its rapid growth phase. The use of off-the-shelf software and hardware components can allow for a rapid implementation and a great degree of flexibility in the implementation.

The Internet and its underlying IP protocol suite have become the driving force for new technologies. Future extensions will include innovative new solutions including conference bridging, voice and data synchronization, combined real-time and message-based services, text-to-speech conversion and voice response systems.

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COST BENEFIT ANALYSIS FOR CONSTRUCTION PROJECTS

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ABSTRACT

Cost Benefit Analysis (CBA) is a common framework for evaluating the benefits and drawbacks associated with any particular project. The technique has the advantage that all costs and benefits are taken into account before finalizing the project. Using a case study, this paper presents the methodologies that can be applied while conducting Cost Benefit Analysis for construction projects.

INTRODUCTION

We are living in a civilized society which demands that much more thoughts should be given to all possible alternative schemes before arriving at the best solution obtainable. Our old price mechanism is purely set on profitability and perfectly copes with the situations where financial costs and returns are the only considerations. However, today's civilized society cannot accept that everything is governed purely by profit. Society wants better facilities for health, education and to preserve the environment in which it lives. Certain pressure groups are constantly pursuing the governments to control the noise, dust, atmospheric pollution, ecological conservation, provide better health facilities and open spaces within urban areas. All these can only be provided to the public if the governments properly evaluate the social benefits and losses of the schemes before launching them.

Another demand of today's society is that it wants to be benefited from the schemes whether directly or indirectly. It is often observed that a benefit to one part of society is not necessarily a benefit to the whole of the society. Of course, by benefiting some sectors of the community, often incurs costs to the other sectors. For example a factory may provide employment but at the same time also causes pollution and devaluing of local house prices, due to noise, increased road transport etc.

On the other hand, the government problems are the annual population growth rate and increase in average human age which is consuming a major part of available funds/resources. In Europe, Germany is facing the worst situation. Population Director of UNO has released a report in October, 1998 which states that the world population would be increased 50% by 2050. Average human age which was just 45 years in 1950 is now 63 years. Europe is badly suffering from the increase in human life where 20% of the population is over 60 years and the said percentage would be increased to 35% by 2050. This situation is threatening social setup (i.e. pension, politics, health etc.) in Europe (UNO Report). In this situation, it is more important for the governments to give special thoughts to the society's demands and try to adopt the schemes which equally benefit the whole society. The objective can be achieved by adopting the Cost Benefit Analysis (CBA), since it is concerned with evaluating schemes for the whole society and not just for isolated sectors. Furthermore, it evaluates the effects on all affected parties that allow the government to control the resentments among a society.

Generally, in any CBA analysis of a scheme researchers initially consider two to three alternatives to find the best net gain for the society. However, a particular scheme giving the highest net gain may not be the one chosen, as the sectors of society who gain and those who lose may not be distributed fairly. For example, if we consider Schemes A & B as shown in Table-1 below, it would be unlikely that society would allow Scheme A to be adopted. Though the Scheme B is not quite financially beneficial to society, but at least it is more evenly weighted to the affected sectors and as such is more likely to be carried out.

Table 1: Comparison of Benefits

Description	Scheme-A	Scheme-B
Cost to wealthy	-	-
Benefit to wealthy	$ 2.0 M	$ 0.8 M
Cost to poor	$ 0.2 M	-
Benefit to poor	-	$ 0.8 M
Total benefit	**$ 1.8 M**	**$ 1.6 M**

During carrying out of evaluations, it should be considered that everyone is made better off by a particular scheme and known as "*pareto improvement*". It is a difficult task; therefore in the majority of schemes, a potential pareto improvement is looked for, where certain sectors of the society benefit and others lose. There is an overall social benefit if the collective benefits are greater than losses; however, not everyone gains individually. Potential Pareto improvement can be converted into a pareto improvement if costless transfers of goods and/or money can take place among the various sectors of society. Transfer payments are those made other than in exchange for productive services. The most common form of transfer payments consists of those operated by a government. Here, the payments are taken from certain sectors of the community in the form of income taxes etc., and are given to the poorer sectors in the form of grants, subsidies, etc. (Shutt, 1997).

If we look back at both schemes as appearing in Table-1, Scheme A seems very unfair but upon considering the transfer payments the final outcome would be as follows (assuming the tax percentage 50%).

Original benefit to wealthy $ 2.0 M,
Transfer via taxes - $ 1.0 M

Original cost to poor $ 0.2 M,
Transfer via state aide +$ 1.0 M

Final benefit to wealthy $ 1.0 M, Pareto improvement
Final benefit to poor $ 0.8 M, Pareto improvement

From the above it can be said that through operation of transfer payments, a grossly unfair situation becomes workable.

METHODOLOGY

Construction management at this time is dominated by three principal approaches that are considered acceptable for research. These are (a) quantitative methods (b) qualitative methods and (c) a combination of both quantitative and qualitative methods, known as a mixed approach. Quantitative methods use deductive thought processes to unveil relationships; the method is underpinned by data collection and analysis. The qualitative approach is drawn from the interpretive philosophical view and uses inductive thought process to determine relationships. Seymour et al. (1995, 1997) strongly argued for the use of "interpretive" (qualitative) approaches over the "rationalistic" (quantitative) approaches often used for construction research. Qualitative approaches yield an investigation that is primarily concerned with meaning as opposed to causality. This unscientific approach was bitterly criticized by the leading researchers such as Runeson (1997) and Harris (1998). On the other hand, despite criticizing, Raftery et al. (1997) were advocates of the combined approach. However, the debate succeeded to advance the mix mode, combining the both quantitative and qualitative approaches. A study of abstracts of papers published in the CEM journal from 1983-1996 revealed that 57% of the researchers utilized quantitative methodological approaches. Only 8% were based upon qualitative research methods, and 13% used a mixed methodology (Loosemore et al., 1996). The remaining papers were classified as "non-

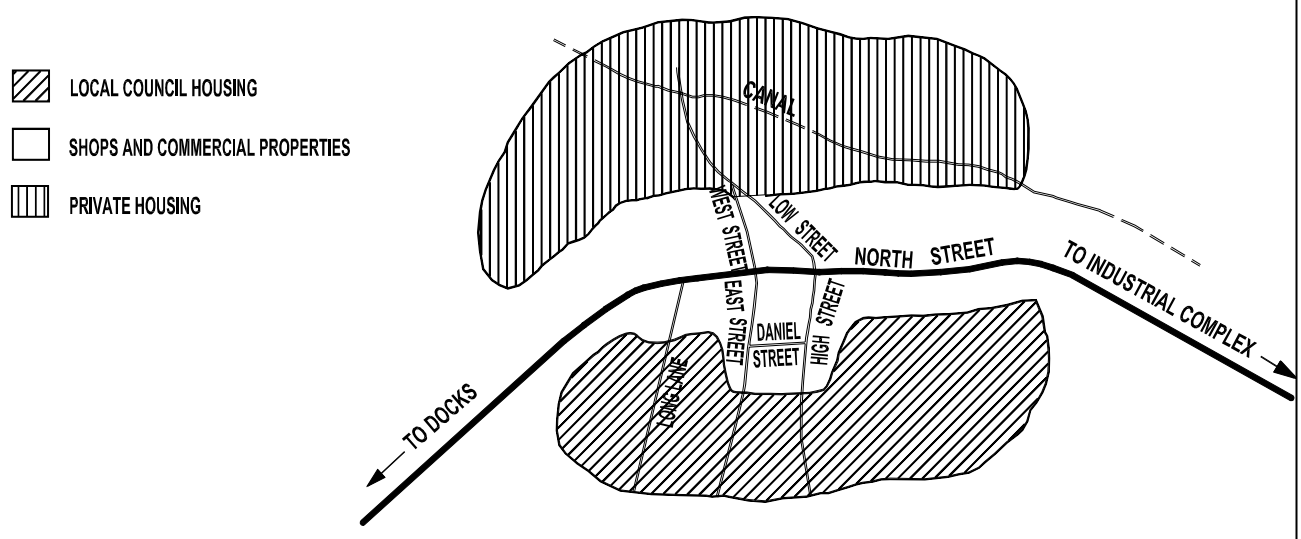

Figure 1: Town as Existing

research" papers. A review of the ARCOM proceeding for the period 1999-2001 shows that the trend of qualitative and mixed mode approaches have increased slightly. However, it remains the case that the quantitative approach dominates construction management research, although it is perhaps noteworthy to mention that many quantitative approaches employ qualitative or subjective methods for the purposes of measuring variables and predictors in models.

In the case of the present study, researcher adopted the combined approach since it is the best for a case study. Approach involved the following steps.

- Identification of the problem.
- Proposal and alternative solutions.
- Identification of the affected sectors.
- Identification of the costs and benefits.
- Quantification of the costs and benefits.
- Summary and conclusions.

IDENTIFICATION OF THE PROBLEM

A town for some years had a problem of increasingly heavy traffic, departing from a growing industrial complex, north of the town, towards the docks, on the south side. The main traffic flow travels along the North Street and has been causing various problems of noise, fumes, congestion and accidents. As a result of a fatal accident, the Local Council became under greater pressure to construct a bypass around the town. Majority of the residents and shopkeepers wanted a bypass, but at the same time, did not want to loose their current property. Town, as existing, is shown in Figure-1.

PROPOSAL AND ALTERNATIVE SOLUTIONS

Scheme-A, B and C as shown in Figure-2, were proposed to Local Council as a possible solution to the problem. Scheme-A involved demolition of 135 Local Council dwellings and 35 shops on the East side of the Daniel Street, in addition to construction of a new fly over on the Long Lane. The total length of this bypass was 6.5 KM. Scheme-B involved demolition of 110 private dwellings and 60 shops in addition to construction of 7.5 KM bypass. Scheme-C involved no demolition. The length of this bypass was 11.5 km.

IDENTIFICATION OF THE SECTORS AFFECTED

Direct involvement of following sectors was identified.

a. The Local Council
b. Existing owners of private housing.
c. Existing tenants of Local Council housing.
d. Existing owners and tenants of shops and commercial properties.
e. Telecommunication Department.
f. Power Department
g. Gas Department.
h. Water and Drainage Department.

IDENTIFICATION OF THE COSTS AND BENEFITS

Following costs and benefits were determined for all the three Schemes.

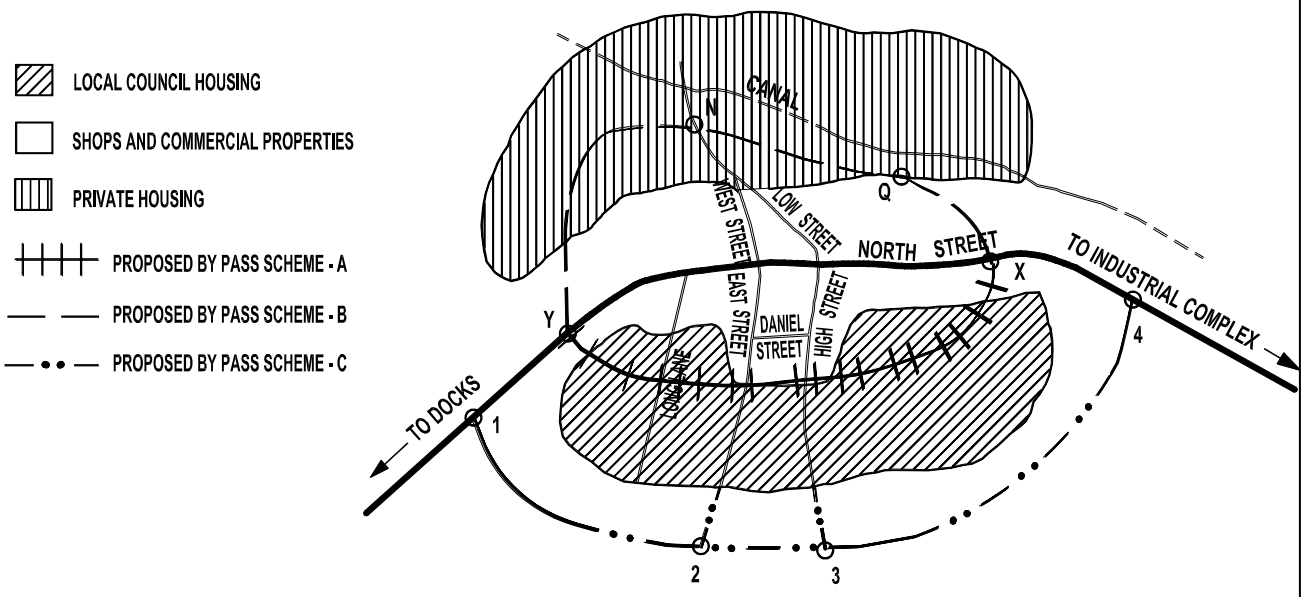

Figure 2: Proposed Bypass Scheme A, B and C for Town

Scheme-A

Benefits:

- Safer, less congested travel for road users.
- Less noise and smoke for commercial area.
- Employment opportunities for the local residents during construction of bypass.
- Safety, health and welfare of shoppers increased.

Costs:

- Financial cost of the scheme.
- Loss of 135 Local Council dwellings
- Loss of 35 shops owned by private sector.
- Noise and pollution transferred from commercial area to residential area.
- Reduction in Local Council house values close to new road.
- Botheration to local residents during construction of bypass.
- Botheration to local residents whose shops or houses are included in demolitions.

Scheme-B

Benefits:

- Safer, less congested travel for road users.
- Less noise and smoke for commercial area.
- Employment opportunities for the local residents during construction of bypass.
- Safety, health and welfare of shoppers increased.

Costs:

- Financial cost of the scheme.
- Loss of 110 private dwellings.
- Loss of 60 shops owned by private sector.
- Noise and pollution transferred from commercial area to residential area.
- Reduction in private house valves close to new road.
- Botheration to local residents during construction of bypass.
- Botheration to local residents whose shops or houses are included in demolitions.

Scheme-C

Benefits:

- Totally safe, less congested and fast travel for road users.
- Reduction in noise and smoke for commercial area.
- Further reduction of noise and smoke for residential areas.
- Employment opportunities for local residents during construction of bypass.

Costs:

- Financial cost of the scheme only.

In summary, it can be said that the costs and benefits of the Schemes- A & B are similar to each other, whereas the Scheme-C is totally different, and contains more benefits as compared to the relevant costs. It should be noted that the cost is a secondary issue in any CBA study.

QUANTIFICATION OF THE COSTS AND BENEFITS

CBA analysis attempts to put an explicit monetary value on items which are not traded in the market, and are therefore not priced, e.g. pollution, noise, dust, etc. In CBA analysis, where a definite cost or benefit can be recognized but impossible to allocate a value in the form of actual figures. The following abbreviations along with a sign of plus (+) or minus (-) are used, following the indicating letter. Normally minus (-) indicates costs and plus (+) denotes benefits. The quantity of symbols of plus (+) or minus (-) signs would indicate the intensity (Shutt, 1997).

a) Abbreviation used when there is a one time only cost or benefit.

M indicates money.
P indicates physical.
T indicates time.
I indicates intangible.
N indicates number.

b) Abbreviation used where there is an annual flow of cost or benefit.

m indicates money.
p indicates physical.
t indicates time.
i indicates intangibles
n indicates number.

This technique is generally known as "quantifying the unquantifiable". Using above techniques the following was quantified for the case study.

A) Cost of Schemes to Local Council

Estimated cost of schemes to Local Council is shown in Table-2.

Table 2: Estimated Cost of Scheme to Local Council

No.	Description	Scheme-A	Scheme-B	Scheme-C
1.	Road construction	$ 3.25 m	$ 3.75 m	$ 6.95
2.	Bridge construction over long lane	$ 2.00 m	-	-
3.	Purchase & demolition cost of shops	$ 6.00 m	$ 12.00 m	-
4.	Purchase & demolition cost of houses	$ 27.00 m	$ 33.00 m	-
5.	Cost of land for road	-	-	$ 3.00 m
6.	Cost of services such as telephone/power	$ 1.00 m	$ 1.00 m	$ 0.50 m
	Total capital cost	**$ 39.25 m**	**$ 49.75 m**	**$ 10.45 m**

B) Existing Owners of Private Housing

Scheme-A & C will not affect the private housing. However, 110 private dwelling would be demolished if scheme-B is adopted. The owners will receive the compensations, but it seldom covers all costs involved, particularly with soft furnishing. There would, therefore, be a monetary cost or M --. There would also be the intangible cost i -- of moving house. Since 110 families would be affected, therefore, we considered the monetary cost M-110 and intangible cost i-110. It will also cost an amount of 33 m $ to Local Council.

C) Existing Tenants of Local Council Housing

Scheme-B & C will not affect this sector. However, 135 dwellings would be demolished if the scheme-A is adopted. Local Council will loose a rent of 0.80 m $ per annum as well as a property of 27 m$. On the other hand 135 families would be affected with intangible cost of moving houses that can be shown as i-135.

D) Existing Owners and Tenants of Shops and Commercial Properties

In Scheme-A, 35 shops and in scheme-B, 60 shops would be demolished. Following the above stated method, we consider the monetary cost M-35/M-60 for shop owners and intangible cost i-35/i-60 for tenants respectively. However Scheme-C will not affect this sector. It will also cost an amount of 6.0 m $ and 12.0 m $ to Local Council respectively.

E) Industrial Complex Using Heavy Transport

For heavy transport to reach from Point "X" to "Y" on existing route takes 20 minutes while using Sscheme-A & B, it would take 6.5 minutes, which means 3 times better or can be indicated as t +++. If scheme-C is implemented then it would take 5 minutes (due to free road) which means 4 times better or can be indicated as t ++++.

F) Traveling by Car

The residents of 'town' will get the similar benefit of time as stated for heavy traffic (Item-E above) while traveling by car.

G) Safety

Safety for local residents will also increase. Using Traffic Police statistics for the Scheme-A & B, it will be enhanced as much as twice, which can be indicated as S++, and for Scheme-C, it will be 4 times (due to totally out of town), and can be indicated as S++++.

Some other benefits and costs such as decrease in house values can also be considered, however, were not included in the study.

Table-3, 4 and 5 represents the findings of CBA analysis for proposed schemes-A, B and C as compared to existing situation. Table-6 represents the summary and order of the preference for all three schemes.

Table 3: CBA Analysis for Scheme-A as Compared to Existing Situation

Sectors involved	Costs	Benefits	Balance
A. The Local Council	$ 39.25 m	-	- $ 39.25 m
B. Existing owners of private housing	-	-	-
C. Existing tenants of Local Council housing	i-135	-	i-135
D. Existing owners/tenants of shops/commercial properties	M-35, i-35	-	M-35, i-35
E. Industrial complex using heavy transport		t +++	t +++
F. Traveling by car		t +++	t +++
G. Safety		S ++	S ++

Table 4: CBA Analysis for Scheme-B as Compared to Existing Situation

Sectors involved	Costs	Benefits	Balance
A. The Local Council	$ 49.75 m	-	-$ 49.75 m
B. Existing owners of private housing	M-110, i-110	-	M-110, i-110
C. Existing tenants of Local Council housing	-	-	-
D. Existing owners/tenants of shops/ commercial properties	m-60, i-60	-	m-60, i-60
E. Industrial complex using heavy transport		t +++	t +++
F. Traveling by car		t +++	t +++
G. Safety		s ++	s ++

Table 5: CBA Analysis for Scheme-C as Compared to Existing Situation

Sectors involved	Costs	Benefits	Balance
A. The Local Council	$ 10.45 m	-	-$ 10.45 m
B. Existing owners of private housing	-	-	-
C. Existing tenants of Local Council housing	-	-	-
D. Existing owners/tenants of shops/commercial Properties	-	-	-
E. Industrial complex using heavy transport	-	t ++++	t ++++
F. Traveling by car	-	t ++++	t ++++
G. Safety	-	s ++++	s ++++

Table 6: Summary of Findings and Order of Preference

Sectors Involved	Scheme-A	Scheme-B	Scheme-C	Order of Preference		
				A	B	C
A. The Local Council	-$ 39.25 m	-$ 49.75 m	-$ 10.45 m	2	3	1
B. Existing owners of private housing	-	M-110, i-110		1	2	1
C. Existing tenants of local council housing	i-135	-	-	2	1	1
D. Existing owners/tenants of shops/commercial properties	M-35, i-35	-	-	2	3	1
E. Industrial complex using heavy transport	t +++	t ++++	t ++++	2	2	1
F. Traveling by car	t +++	t ++++	t ++++	2	2	1
G. Safety	s ++	s +++	S ++++	2	2	1
			Preference Totals	**13**	**15**	**7**
			Overall Order of Preference	**2**	**3**	**1**

CONCLUSIONS

CBA analysis demonstrates that the financial implications of Scheme-A and B are 4 to 5 times higher than the Scheme-C. In addition to huge financial implications, the both Schemes have definite costs in terms of "*Money*" and "'*intangibles*" that will affect the Local Council and public as well, especially when the local area residents are not willing to vacate the property. Benefits in terms of "*time*" and "*safety*" are also lesser as compared to Scheme-C. On the other hand, the Scheme-C has no definite costs for "*Money*" and "'*intangibles*" that may affect the Local Council or Public. Consequently, Scheme-C presents the best solution to the problem for people of the town.

ACKNOWLEDGEMENTS

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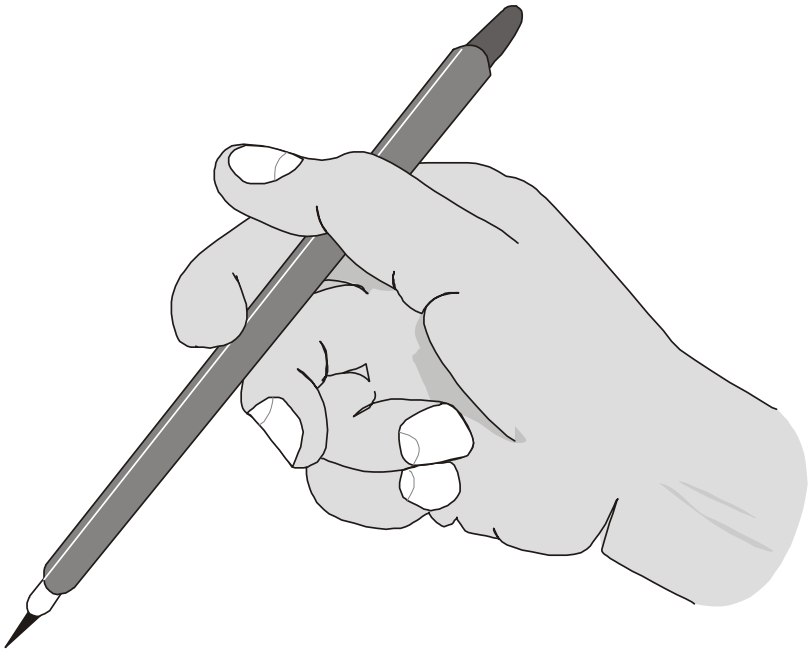

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ABDUL QADIR AKBANI	Mechanical	(03) 857-4150
ABDUL QAYYUM	Electrical	(01) 462-2011 / 465-6613
ABDUL QAYYUM QURESHI	Electrical	(03) 843-3404
ABDUL QUDDUS	Mechanical	(03) 860-3533
ABDUL QUDDUS M.	Mechanical	(01) 464-3333 x 4803
ABDUL RAHMAN LALDIN	Electrical	(03) 858-6914
ABDUL RAUF	Electrical	(01) 478-5448
ABDUL REHMAN	Chemical	(01) 477-9111 x 322
ABDUL SATTAR	Electrical	(01) 239-7320
ABDUL WAHEED	Mechanical	(03) 857-2300 x 84979
ABDUL WAHEED BUTT	Electrical	(01) 265-0090 x 1564
ABDUL WAHEED KHAN	Civil	(01) 477-7222 x 168
ABDUL WAHEED MIR	Electrical	(01) 403-2222 x 14546
ABDUR RASHID HAQ	Civil	(02) 622-4444 x 580
ABDUR RASHID SHAD	Civil	(01) 474-0111 x 218
ABID WASEEM ASLAM	Civil	(01) 476-8118
ABID ZAMAN KHAN	Mechanical	(01) 478-9000 x 4610
ADEEL BIN AFZAL	Electrical	(01) 293 5661
AFAQ HUSSAIN SIDDIQI	Civil	(01) 403-7878 x 430
AFTAB AHMAD MALIK	Mechanical	(03) 882-6666 x 2806
AFTAB AHMED	Civil	(02) 667-0500 x 117
AFTAB ALAM	Civil	(02) 542-6421
AFTAB KHAN	Electrical	(01) 491-1333 x 305
AFTAB NASEER	Civil	(01) 464-1498
AFZAAL SHAIQ QADRI	Chemical	(01) 523-1489
AFZAL MAJID	Electrical	(03) 858-5449
AGHA ZIA-UL-HASSAH	Mechanical	(01) 465-4235 x 105
AHMAD NADEEM	Electrical	(03) 8473020
AHMAD SOHAIL SIDDIQUI	Electrical	(01) 452-8896
AHMAD WARAICH	Civil	(01) 454-9191 x 245/267
AHSAN AHMED RANA	Electronics	(01) 452-6239
AHSAN ALI LOONA	Mechanical	(01) 476-8686 x 108
AHTSHAM AHMED	Mechanical	(02) 550-6273 x 330
AKHTAR JAWAID NIAZI	Civil	(03) 832-6402
ALEEM PIRACHA	Electronics	(03) 358-4744 x 8981
ALI AKBAR	Electrical	(01) 465-6150
ALTAF HUSSAIN KHAN	Electrical	(01) 465-9975 x 206
AMIR BIN RAUF	Mechanical	(03) 357-7276
AMJAD RASHEED	Electrical	(01) 275-5999 x 815
ANIS AL-HASAN	Civil	(02) 667-6612
ANIS UR REHMAN KHAN	Civil	(03) 864-2642
ANJUM K. ALVI	Mechanical	(03) 343-0333 x 30719
ANJUM SAEED	Civil	
ANWAR KHALIL SHEIKH	Mechanical	(03) 860-2575
ANWAR NAZAR ALI	Electrical	(01) 465-2260 / 463-3417
ANWAR RAZA KHAN	Mechanical	(03) 340-1627
ANWAR UL HAQ	Civil	(01) 485-4644
AQIL NASIR MIRZA	Electrical	(03) 357-7603
ARIF HABIB	Electrical	(03) 864-0091
ARIF ISLAM BUTT	Electronics	(02) 651-9998 x 231
ARSHAD ALI	Electrical	(07) 227-1111 x 1328
ARSHAD ALI AMJAD, DR.	Civil	
ARSHAD HUSSAIN	Electronics	(01) 493-6622 x 260
ARSHAD HUSSAIN	Civil	(01) 455-2708 x 523
ARSHAD JAMAL	Electrical	(01) 222-1340
ARSHAD M. CHOHAN	Architecture	(02) 675-7253
ARSHED ALI	Electrical	(01) 477-6666 x 6169
ARSLAN AHMED	Mechanical	(01) 245-3681 x 9765
ASAD NAVEED	Electrical	(03) 860-4069
ASHFAQ MOHAMMAD	Architecture	(01) 464-1188 x 232
ASIF ABBAS ZAIDI	Mechanical	
ASIF MAJEED	Electrical	(01) 245-2434
ASIF MAQSOOD SHEIKH	Mechanical	(01) 477-5192
ASIF RASUL	Electrical	(01) 435-5125 x 1868
ASIF ZAFAR	Mechanical	
ASRAR KHAN GHORI	Civil	(01) 465-8665 x 258
ASRAR M AHMED	Civil	(02) 542-6421
ASRARUL HAQ SHEIKH	Electrical	(03) 860-1182
ATA UR RAHMAN	Civil	(04) 392-5316
ATEEQ UR REHMAN	Metallurgy	
ATHAR ALIM KHAN	Mechanical	(01) 488-2226 x 23
ATHAR S. KHWAJA	Civil	(03) 894-8215 / 898-2240
ATHER JAMIL DAR	Electrical	(01) 452-8847
AZHAR I. KHAN	Electrical	(02) 665-8420
AZIMUDDIN QURESHI	Electrical	(02) 653-1765 x 233
AZIZ AKHTAR CHOUDERY	Electrical	(01) 464-3333 x 14864
AZIZ ARSHAD	Miscellaneous	(03) 860-2761
AZIZ UR RAHMAN	Civil	(01) 478-0574
AZIZ ZARULLAH KHAN	Miscellaneous	(03) 830-2396
BABAR SULTAN	Civil	(03) 889-1576 x 14
BADAR UZ ZAMAN	Mechanical	(03) 357-5757
BAZURJ MEHR KHAN	Electrical	(01) 442-2000 x 360
BILAL AKHTAR	Electrical	(03) 882-5669 x 244
CHAUDHARY GULRAIZ	Civil	(01) 211-0087
CHAUDHARY M. SHARIF	Electrical	(01) 464-3333 x 14354
CHAUDHARY	Mechanical	(03) 357-8805
CHAUDHARY RIAZ	Computer	(03) 860-2139
CHAUDHRY SARFARAZ	Electrical	(03) 860-2134
CHOUDHARY	Electrical	(01) 477-9111 x 155
DEEDAR ALI	Electronics	(01) 452-9187
DIWAN Y. DAWOOD	Electrical	(03) 673-2833
EBRAR AHMED SHAMS	Civil	(03) 586-2144
EHSANUL HAQUE	Electrical	(02) 639-0172
EHSAN-UL-HAQUE	Electrical	(01) 246-2776 x 36
ENAYAT-ULLAH KHAN	Electrical	(01) 442-2000 x 312
FAHAD KARIM KHAN	Electrical	(03) 857-2537
FAHEEM ELAHI ANSARI	Chemical	(02) 686-4288

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NAME	DISCIPLINE	PH. (OFFICE)
FAISAL MALIK	Mechanical	(01) 491-1333 x 385
FAREED AHMED MEMON	Electrical	(07) 227-1111 x 1493
FAREEDUDDIN AHMED	Electronics	(03) 860-2884
FARHAT ALI BURNEY, DR	Mechanical	(02) 695-2251
FAROOQ AHMED BHATTI	Architecture	(03) 895-5004 x 412
FAROOQ AHMED	Electrical	(01) 498-3844
FAROOQ HAMEED	Mechanical	(03) 357-7332
FAROOQ SALEEM IKRAM	Chemical	(03) 340-6663
FASIH AHMED	Civil	(01) 482-3380 / 482-3258
FASIH-UZ-ZAMAN KHAN	Mechanical	(01) 476-3030 x 295
FATEH KHAN	Electrical	(01) 241-2228 x 4126
FAYYAZ AHMED KHAN	Mechanical	(01) 476-3030 x 283
FAYYAZ MUDDASSIR	Mechanical	(03) 343-0333 x 38503
FAZAL-UR-REHMAN AWAN	Metallurgy	(03) 359-9230
GHAZANFAR ALI IQBAL	Electrical	(03) 858-6636
GHUFRAN AHMED	Electrical	(03) 882-5669 x 240
GHULAM ABBAS	Electrical	(01) 405-5143
GHULAM HUSSAIN KHAN	Mechanical	(01) 467-6841
GHULAM SAFDAR	Civil	(01) 226-3727
GHULAM SARWAR	Mechanical	(01) 464-1188
HABIB UR REHMAN	Civil	(03) 893-8495 / 894-9704
HABIBULLAH TALPUR	Mechanical	(01) 241-4364 x 4220
HAFEEZ-UR-REHMAN	Electronics	(01) 472-5000
HAFIZ KHADIM HUSSAIN	Civil	(01) 477-3115 x
HAFIZ MUHAMMAD	Mechanical	(02) 651-9998 x 233
HAMID ALI	Electrical	(03) 586-8600 x 2627
HAMID ALI KHAN	Civil	(01) 454-9191 x 239
HAMID MOHSIN	Electrical	(01) 479-3000
HAMIDUR RAHMAN	Electrical	(01) 478-0320
HASSAN SIDDIQUI	Electrical	(01) 291-2877 x 243
HUMAYUN AKHTAR	Electrical	(01) 419-4962 x 3016
HUSAIN AHMED	Electrical	(03) 378-5510
IFTIKHAR AHMAD QAZI	Chemical	(01) 285-1889
IFTIKHAR AHMED	Electrical	(01) 404-0910
IFTIKHAR AHMED HAJI	Electronics	(01) 452-8184
IFTIKHAR NADEEM	Miscellaneous	(03) 860-3893
IJAZ AHMAD KHAN	Civil	(01) 465-9975 x 115
IJAZ HUSSAIN	Electrical	(01) 472-4473
IKRAM HUSSAIN	Chemical	(03) 860-3085
IMRAN IJAZ	Mechanical	(03) 895-5004 x 145
IMRAN SULTAN	Mechanical	(03) 857-7710
IMTIAZ AHMED	Civil	(01) 295-3015
IMTIAZ AHMED DURRANI	Civil	(02) 671-5621
IMTIAZ KHALID	Electrical	(01) 465-5610
INAM KHAN	Electrical	(03) 842-2442
INAM MUHAMMAD	Mechanical	(03) 860-2520
INAYAT ULLAH MEMON	Electrical	(03) 678-8288 x 1071
IQBAL AHMED	Electrical	(01) 478-2027 x 35
IQBAL AHMED KHAN	Mechanical	(03) 677-1104
IQBAL AHMED SIDDIQUI	Electronics	(01) 445-7622 /445-7544
IQBAL HAIDER MALIK	Mechanical	(01) 403-2222 x 1372
IQBAL HUSSAIN	Civil	(01) 478-1444 / 477-8309
IQBAL ISMAIL KHURRAM	Electrical	(01) 239-7497
IRFAN AHMED CHISHTI	Civil	(04) 322-8636
IRFAN ALI KHAN	Mechanical	(01) 474-5296
IRFAN BROHI	Mechanical	(03) 857-3559
IRFAN ELAHI	Mechanical	(03) 341-5939 / 03-
IRSHAD AHMED	Mechanical	(07) 227-1111 x 1615
IRSHAD NABI	Civil	(01) 465-6975
ISLAM AHMAD ASIF	Electrical	(03) 889-1609 x 1576
ISLAM MUSHEER KHAN	Mechanical	(03) 854-2058
ISMET AMIN KHAWAJA	Civil	(03) 864-6593
ISRAR UL HAQ	Electrical	(01) 246-6500 x 235
ISRAR ULLAH KHAN	Civil	(03) 357-5062
JALEEL HASAN	Electrical	(01) 217-9011
JAMAL NISAR KHAN	Electrical	(02) 669-6909 x 185
JAMIL A. WARSI	Mechanical	(01) 463-3330
JAMSHED MUSTAFA	Computer	(01) 467-5147
JAVAID HAMEED	Electrical	(03) 858-6350
JAVAID IQBAL	Civil	
JAVED IQBAL	Civil	(03) 865-6982
JAVED M. AHSANI	Electronics	(01) 460-0590
JAVED NADEEM	Electrical	(03) 882-9546
JAVED SAFDAR	Electrical	(03) 858-6747
JAVED SHAMIM	Electrical	(01) 452-7928
JAWAID INAM	Electrical	(03) 864-8371
JAWAID IQBAL	Mechanical	(02) 654-5683 / 692-0422
JAWED ANWER	Miscellaneous	(03) 872-8374
JAWED IQBAL	Civil	(01) 491-1139 x 2230
JUNAID AHMAD HASHMI	Electrical	(01) 401-4806
KAFEEL AMEEN KHAWAJA	Miscellaneous	(03) 864-6593
KAMRAN ASIF ASLAM	Electronics	(01) 2466697 ext 109
KARAMAT ULLAH	Electrical	(03) 361-0333 x 30774
KAUSER MAHMOOD BUTT	Electrical	(01) 403-2222 x 23196
KAWISH ABBASI	Civil	
KHALED MASOOD	Mechanical	(01) 476-6500
KHALID ALI	Mechanical	(07) 227-1111 x 1358
KHALID HABIBULLAH	Electronics	(01) 403-2222 x 1329
KHALID HUSSAIN KHAN	Electrical	(03) 812-1155
KHALID IQBAL WARRAICH	Architecture	(01) 249-9983
KHALID LATIF	Mechanical	(03) 357-7609
KHALID MAHMOOD DR.	Civil	(02) 695-2250
KHALID NADEEM	Electronics	(02) 650-4744 x 478
KHALIL AHMED	Computer	(01) 477-6777 x 3417
KHALIL UR REHMAN SHAH	Mechanical	(01) 442-7686
KHAWAJA GHULAM	Mechanical	
KHAWAR IQBAL KHAN	Mechanical	(02) 531-7420
KHIZAR JUNAID USMANI	Electrical	(01) 265-3030 x 1562
KHURRAM KARAMAT	Civil	(01) 465-9975 x 107
KHURRAM SHAHID	Computer	(01) 478-1212 x 227
KIRMANI SYED	Civil	(01) 465-3127
KUNWAR MUHAMMAD	Electrical	(02) 672-9913
LAIQUE HAIDER	Civil	(03) 862-5481
LIAQAT ALI KHAN	Electrical	(03) 586-8600 x 62739
LIAQAT ALI SAHI	Mechanical	(03) 873-8959
M. ASHRAF KHAN	Electrical	(01) 265-1515 x 626
M. FEROZE SAYEED	Mechanical	(03) 834-4500 x 603
M. IMRAN ASGHAR	Mechanical	(03) 3575709
M. IRSHAD A. USMANI	Electrical	(03) 843-1874
M. JAVED AKHTAR	Electrical	(03) 895-5004
M. JAVED IQBAL	Electrical	(03) 889-1609
M. SHABBIR SHEKHANI	Electrical	(03) 882-1111 x 5050

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NAME	DISCIPLINE	PH. (OFFICE)
M. SHAHID MUNIR	Mechanical	(03) 895-5004
M. WAHEED CHUGHTAI	Civil	(01) 239-7619
M.J.K. ZARRAR SHARIF	Mechanical	(01) 435-8422 x 1686
MAHMOOD USMAN	Electrical	(07) 227-1111 x 1128
MAHMOOD-AL-HASSAN	Electronics	(03) 343-0333 x 39300
MAJID LATIF	Electronics	(01) 476-3777 x 141
MALIK HUMAYOON IQBAL	Civil	(01) 478-9000 x 4635
MALIK ZUBAIR	Electronics	(03) 887-0188 x 253
MAQBOOL AHMED BHATTI	Mechanical	(01) 419-6425
MAQBOOL HUSSAIN	Miscellaneous	(01) 465-9975 x 249
MAQBUL AHMED	Mechanical	
MAQSOOD ALAM	Electrical	(01) 265-0515
MAQSOOD HAMID	Chemical	(03) 357-7220
MAQSOOD HUSSAIN	Electrical	(02) 667-0500
MAROOF AHMED JAFFERI	Mechanical	(03) 858-0511 x 216
MASOOD ELAHI	Mechanical	(01) 251-3559 / 251-3465
MASOOD HAMID	Electrical	(02) 697-2620 / 697-6958
MASOOD SAID	Mechanical	(02) 663-5666
MASOOR AHSAN	Electrical	(02) 686-4855
MASROOR AKBAR RAMZI	Electrical	(01) 403-2222 x 23150
MASUD UL HASAN	Computer	(03) 860-2362
MAZHAR NAWAZ KHAN	Electrical	(03) 835-8807
MAZHAR NOOR	Electrical	(01) 206-0000 x 3326
MEHZAD SAHAR	Electrical	(03) 872-8586
MIAN FAHEEM-UL-GHANI	Electronics	
MIAN SHAMIM AHMAD	Mechanical	(01) 464-1188 / 488-4722
MIR MAJID TAUSEEF	Electrical	(01) 464-3333 x 14317
MIR SARFARAZ ALI KHAN	Civil	(03) 895-5004 x 465
MIR ZAMAN KHAN	Mechanical	(02) 654-7171
MIRZA AHTESHAM UD DIN	Civil	(02) 667-2082
MIRZA ZAMIR AHMED	Electrical	(01) 2755999x 806
MOBASHIR AHMED	Electrical	(02) 663-4442
MOHAMMAD ABBAS	Mechanical	(03) 341- 0109 x 3517
MOHAMMAD ABDUL	Electrical	(03) 832-4400 x 148
MOHAMMAD ABDUL	Civil	(03) 858-6629
MOHAMMAD ABDULLAH	Electrical	(03) 895-5004 x 150
MOHAMMAD ABRAR	Electrical	(07) 227-1111 x 1328
MOHAMMAD ADIL	Civil	(03) 847-1500 x 1502
MOHAMMAD AFZAL	Electrical	(03) 857-9126 x 3536
MOHAMMAD AFZAL	Civil	(03) 341-3096
MOHAMMAD AFZAL	Civil	(03) 859-1999
MOHAMMAD AFZAL	Electrical	(03) 894-3025
MOHAMMAD AJMAL KHAN	Electrical	(01) 477-6777 x 1553
MOHAMMAD AKHTAR	Electrical	(03) 586-8600 x 62924
MOHAMMAD AKRAM	Electrical	(01) 476-9777 x 42550
MOHAMMAD AKRAM	Electrical	(03) 341-4276
MOHAMMAD ALIUDDIN	Civil	(03) 766-0055 x 4079
MOHAMMAD AMIN	Electrical	(03) 533-2222 x 1111
MOHAMMAD AMIN UDDIN	Electrical	(03) 833-7110
MOHAMMAD AMON KHAN	Electrical	(03) 678-8465
MOHAMMAD ANWAR	Civil	(02) 631-2280 x 514
MOHAMMAD ANWAR	Mechanical	(01) 477-6777 x 1371
MOHAMMAD ANWAR	Civil	(03) 883-2377
MOHAMMAD ARIF	Mechanical	(01) 245-3681 x 9751
MOHAMMAD ARSHAD	Mechanical	(01) 464-3500 x 450
MOHAMMAD ARSHED	Electrical	(01) 403-2222 x 23199
MOHAMMAD ARSHED	Mechanical	(07) 227-1111 x 1358
MOHAMMAD ASGHAR	Mechanical	(03) 341-7658
MOHAMMAD ASGHAR	Mechanical	(03) 357-7084
MOHAMMAD ASHFAQ	Electrical	(01) 265-0515 / 406-6669
MOHAMMAD ASHRAF	Electrical	(01) 477-7947 x 108
MOHAMMAD ASHRAF	Electrical	(03) 857-2300 x 84502
MOHAMMAD ASHRAF	Electrical	(01) 467-6692
MOHAMMAD ASLAM	Electrical	(01) 464-1498
MOHAMMAD ASLAM	Electrical	(01) 291-2000 x 415
MOHAMMAD ASLAM	Miscellaneous	(03) 889-1609
MOHAMMAD ASLAM	Electrical	(03) 895-5004 x 425
MOHAMMAD ASLAM KHAN	Electrical	(01) 498-0391 x 18
MOHAMMAD ASLAM	Mechanical	(03) 341-0671 x 246
MOHAMMAD ATIQULLAH	Electrical	(03) 894-6816
MOHAMMAD AWAIS	Electrical	(03) 362-1824 x 76510
MOHAMMAD AYAZ QUTUB	Electrical	(01) 458-2222 x 3597
MOHAMMAD AYOUB WALI	Metallurgy	(03) 817-5133
MOHAMMAD AZAM	Electrical	
MOHAMMAD AZAM	Electrical	(02) 574-9045 x 404
MOHAMMAD FAHEEM	Civil	(03) 812-2967 x 239
MOHAMMAD FAHEEM	Mechanical	(03) 588-3641
MOHAMMAD FAHIM	Civil	
MOHAMMAD FAWAD	Civil	(01) 464-9835 / 462-3955
MOHAMMAD FAWAD	Electronics	(01) 492-6818
MOHAMMAD FAZLUL AMIN	Mechanical	(01) 245-3681 x 9335
MOHAMMAD FEROZE	Mechanical	(03) 894-6816 x 255
MOHAMMAD HAFEEZ-UR-	Electrical	(03) 341-4223
MOHAMMAD HANIEF	Electronics	(01) 498-0088 x 1371
MOHAMMAD HASAN	Civil	(03) 891-2838
MOHAMMAD HASEEB NAZ	Computer	(01) 246-3696
MOHAMMAD HASSAN	Electrical	(01) 462-9995
MOHAMMAD HUSSAIN	Electrical	(01) 458-2222 x 3502
MOHAMMAD HUSSAIN	Mechanical	(03) 857-7710
MOHAMMAD IBRAHIM	Civil	(01) 478-9000
MOHAMMAD IDREES	Electrical	(03) 231-2222 x 3742
MOHAMMAD IDREES	Civil	(01) 464-1611
MOHAMMAD IFTEKHAR-	Civil	(01) 464-9688
MOHAMMAD IFTIKHAR	Metallurgy	(03) 864-4111
MOHAMMAD ILYAS	Electrical	(02) 671-4774
MOHAMMAD ILYAS	Electrical	(01) 452-7664
MOHAMMAD ILYAS SHAH	Civil	(03) 889-1609
MOHAMMAD IMAMUDDIN	Electronics	(03) 857-2595
MOHAMMAD IMTAR	Electrical	(03) 857-7000
MOHAMMAD IQBAL	Mechanical	(02) 669-5851
MOHAMMAD IQBAL	Electrical	(02) 684-1693
MOHAMMAD IQBAL	Electrical	(01) 467-6963
MOHAMMAD IQBAL	Electronics	(01) 467-6069
MOHAMMAD IQBAL	Electrical	(01) 452-9362
MOHAMMAD IRFAN	Electronics	(07) 227-1111 x 1128
MOHAMMAD ISHAQUE	Mechanical	(01) 221-2067
MOHAMMAD ISHTIAQ	Electrical	(03) 341-7493
MOHAMMAD ISRARUL	Mechanical	(03) 858-6529
MOHAMMAD JAFAR KHAN	Civil	(03) 897-1050
MOHAMMAD JAMSHAID	Mechanical	(03) 574-4134
MOHAMMAD JASIM	Civil	(01) 252-0088 x 4559
MOHAMMAD JAWAID	Electrical	(02) 682-7337

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NAME	DISCIPLINE	PH. (OFFICE)
MOHAMMAD KALIMUR	Civil	(03) 860-1129
MOHAMMAD KASSIM	Electrical	(01) 265-3030 x 1337
MOHAMMAD KHALID	Electrical	(02) 682-7337
MOHAMMAD KHALID	Electrical	(03) 895-5004 x 322
MOHAMMAD KHURSHID	Civil	(01) 464-9688
MOHAMMAD MAHFOOZ	Civil	(01) 241-6111
MOHAMMAD MAHMOOD	Electrical	(03) 892-2300 x 2503
MOHAMMAD MAHMOOD	Mechanical	(04) 392-5316
MOHAMMAD MAHMUD	Electrical	(01) 402-6809 x 309
MOHAMMAD MAHTAB	Electrical	(02) 684-2691
MOHAMMAD MANSHA	Electrical	(01) 2312222 x13733
MOHAMMAD MANSOUR	Architecture	(01) 465-6796
MOHAMMAD MAROOF-UZ-	Electrical	(02) 697-7723
MOHAMMAD MASOOD	Civil	(01) 454-9191 x 214
MOHAMMAD MOAZAM	Civil	(01) 464-1611
MOHAMMAD	Electrical	(01) 426-0018 x 8231
MOHAMMAD MUSLIM	Electrical	(01) 454-8121
MOHAMMAD NAEEM	Electrical	(03) 857-2300 x 84561
MOHAMMAD NASIM	Electrical	(01) 403-2222 x 10208
MOHAMMAD NAVEED	Electrical	(03) 361-3407
MOHAMMAD NISAR	Electronics	(03) 343-0333 x 30713
MOHAMMAD NOOR ALAM	Electrical	(01) 401-5555 x 1364
MOHAMMAD PARVEZ	Mechanical	(01) 491-1333 x 325
MOHAMMAD RAFIQUE	Electrical	
MOHAMMAD RASHAD	Electrical	(01) 478-9000 x 3761
MOHAMMAD RASHID	Civil	(03) 592-4445
MOHAMMAD RASHID QAZI	Electrical	(03) 362-1824 x 76597
MOHAMMAD RASHID	Electrical	(02) 663-7854
MOHAMMAD SADIQ KHAN	Electrical	(01) 403-2222 x 3249
MOHAMMAD SAEED	Mechanical	(03) 8873868 ext 202
MOHAMMAD SAFDAR	Electrical	(03) 858-7536 x 3303
MOHAMMAD SAGHIR	Mechanical	(01) 462-2888
MOHAMMAD SAJJAD	Civil	(03) 574-4112
MOHAMMAD SALEEM	Electrical	(03) 8473020 x 232
MOHAMMAD SALEEM	Electrical	(01) 403-2222 x 1894
MOHAMMAD SALEEM	Civil	(03) 860-2691
MOHAMMAD SALEEM	Architecture	(02) 654-7171 x 388
MOHAMMAD SARDAR	Electrical	(01) 452-7493
MOHAMMAD SHAFIQ	Electrical	(01) 464-9811 x 430
MOHAMMAD SHAFIQ	Civil	
MOHAMMAD SHAKIL	Chemical	
MOHAMMAD SHAUKAT ALI	Electrical	(07) 227-1111 x 1410
MOHAMMAD SHEHBAZ	Mechanical	(03) 897-1050 x 272
MOHAMMAD SHER UMAR	Electrical	(03) 857-7738 x 242
MOHAMMAD SULAIMAN	Mechanical	(01) 463-1111 x 2111
MOHAMMAD TAHIR JAMIL	Civil	(03) 833-2266
MOHAMMAD TAHIR	Civil	(01) 460-4845
MOHAMMAD TARIQ	Mechanical	(01) 464-9688
MOHAMMAD TARIQ	Chemical	(03) 857-9922
MOHAMMAD TARIQ	Mechanical	(01) 403-2222 x 1720
MOHAMMAD TARIQ SHAFI	Electrical	(03) 857-9922
MOHAMMAD TAUSIF	Electrical	(01) 403-2222 x 23197
MOHAMMAD TAYYIB	Civil	(01) 476-9777 x 42417
MOHAMMAD TOUSEEF	Electrical	(03) 577-1405
MOHAMMAD WAQAR	Mechanical	(04) 396 1366 x 104
MOHAMMAD WASEEM	Architecture	(01) 252-0088 x 4563
MOHAMMAD YAHYA KHAN	Civil	(01) 454-9191 x 292
MOHAMMAD YAQUB	Mechanical	(03) 860-2520
MOHAMMAD YASIN	Mechanical	(03) 678-8288 / 895-5004
MOHAMMAD YOUNAS	Chemical	(01) 285-1878
MOHAMMAD YOUNAS	Mechanical	(03) 860-3049
MOHAMMAD YOUNAS	Chemical	(03) 357-2327
MOHAMMAD YOUSAF	Mechanical	(03) 868-2255 x 234
MOHAMMAD YOUSUF	Civil	
MOHAMMAD ZAFAR	Chemical	(01) 265-0980
MOHAMMAD ZAFAR	Electrical	(01) 441-5958
MOHAMMAD ZAHID	Mechanical	(03) 8576024
MOHAMMAD ZAMURRAD	Electronics	(01) 452-5161
MOHIUDDIN AHMED	Mechanical	(03) 860-3779
MOHSIN TANVIR MALIK	Electrical	(02) 672-5405
MUBEEN UDDIN AHMED	Civil	(04) 328-0178
MUHAMMAD RIAZ	Electrical	(01) 477-6550 x 127
MUJAHID AHMAD	Electrical	(01) 478-9000 x 3976
MUKESH KUMAR	Electrical	(03) 899-5605 / 898-0071
MUNAWAR A. SAUDAGAR	Chemical	(01) 265-3333 x 5545
MUNAWAR HUSSAIN	Electrical	(01) 403-2222 x 1232
MUNEEB AHMAD DAR	Electrical	(07) 227-1111 x 1106
MUNEER AHMED RANA	Civil	(01) 460-7667
MUNIR AHMAD	Civil	(01) 403-1103
MUNIR AHMAD HASRAT	Electrical	(01) 411-2222 x 3324
MUNIR AHMED	Electrical	(01) 265-3030 x 1330
MUNIR AHMED	Civil	(01) 490-0116
MUNIR AHMED JAVID	Civil	(03) 889-1609
MUSHARRAF ALI KHAN	Electrical	(01) 265-0255 x 15
MUSHIR AHMED SIDDIQUI	Electrical	(01) 481-6666 x 318
MUSHTAQ AHMED AZAD	Electrical	(03) 858-5786
MUSHTAQ AHMED	Electronics	(01) 403-2222 x 10346
MUSHTAQ AHMED M.	Electrical	(07) 227-1111 x 1750
MUSHTAQ AHMED	Electrical	(01) 403-2222 x 23203
MUSHTAQ AHMED	Civil	(02) 654-7171 x 159
MUSTAFA IQBAL NASIM	Civil	(01) 401-2550 x 617
MUSTAFA NOEED AHMED	Civil	(03) 842-2442
MUZAFFAR UL HASSAN	Electrical	(01) 241-3300 x 24797
NADEEM ARSHAD SHEIKH	Civil	(01) 465-9975 x 213
NAEEM AKHTAR	Civil	(03) 860-2691
NAEEM UD DIN	Electrical	(01) 241-3236 x 4165
NAEEM ULLAH SHEIKH	Electrical	(01) 265-1573 x 230
NAFIS-UL-HASAN	Mechanical	(01) 498-0020 x 7013
NAJIB REHMAN	Mechanical	(02) 654-7171 x 130
NASIM R.M INAMULLAH	Mechanical	(01) 245-3681 x 9753
NAVEED AHMAD	Electrical	(01) 265-3030 x 1534
NAVEED AKHTAR	Electrical	
NAVEED IQBAL QURESHI	Mechanical	(01) 477-7009 x 27213
NAVEED ULLAH	Civil	(03) 859-4015
NAYER AZAM	Electronics	(01) 416-2222 x 440
NAZAR HUSSAIN MALIK,	Electrical	(01) 467-6783
NAZAR MOHAMMAD	Architecture	(01) 476-3030
NEAZ AHMED	Mechanical	(03) 860-3082
NISAR AHMAD ATTA	Mechanical	(07) 227-1111 x 1295
NISAR BALOCH	Electrical	(01) 291-2877 x 24
NOOR ULLAH KHALID	Architecture	(01) 461-6087 x 166
NOORUDDIN JUNEJO	Civil	(01) 246-1047 x 27

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NAME	DISCIPLINE	PH. (OFFICE)
NUSRAT PERVEZ	Electronics	(01) 463-1277 x 401/404
OBAIDULLAH SIDDIQI	Civil	(01) 476-6566 x
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PERVAIZ IQBAL QURESHI	Civil	(01) 465-6150
QAIM MAHDI	Electrical	(01) 265-1515 x 316
QAIYYUM HASHMI	Civil	(03) 897-1050 x 788
QAMAR UL ISLAM	Computer	(01) 478-3603 x 263
QAMARUL HAQUE	Electrical	(02) 669-5851 x 242
QAZI SALEEM AHMED	Electrical	(02) 669-5851 x 251
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RAJA SHAHID SALEEM	Civil	(03) 833-3997
RANA SARFRAZ AHMED	Electrical	(01) 452-8905
RAO ABDUL RAQEEB	Electrical	(01) 452-6964
RASHID A. BHUTTO	Electrical	(07) 227-1111 x 1320
RAZA HUSAIN	Electrical	(01) 465-9975 x 205
RAZAUR RAHMAN	Electrical	(01) 265-1515 x 255
REHAN NOOR KHAN	Mechanical	(03) 896-6666 x 1045
RIAZ HUSSAIN	Electronics	(01) 452-8712
RIZWAN AHMAD	Electrical	(03) 834-1730
RIZWAN AHMED BHATTI	Civil	(03) 897-1050 x 159
RIZWAN ALI	Mechanical	(03) 341-0671
RIZWAN UL HAQ FAISAL	Electrical	(03) 857-9922 x 227
S. AADIL USMAN FATIMI	Computer	(01) 246-1200
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S. AFZAL HASAN KAZMI	Electrical	(01) 465-2511 x 14
S. AIJAZ HAIDER	Electrical	(02) 6614444 x 2406
S.M. NASEERUDDIN	Electrical	(01) 464-9688
SADAR DIN	Civil	(01) 465-9975 x 203
SAEED RASHID SHEIKH	Mechanical	(01) 476-2539
SAFDAR A. KHAN	Electrical	
SAFDAR IQBAL AWAN	Electrical	(01) 464-3333 x 14386
SAGHIR AHMED	Electrical	(03) 343-0333 x 39204
SAIF UR REHMAN	Mechanical	(01) 491-1333 x 342
SAIFULLAH SALEEM	Mechanical	(01) 243-5099
SAIF-UR-RAHMAN, DR	Mechanical	(03) 860-6688
SAJID ALI KHAN	Electronics	(03) 341-1100 x 863
SAJJAD AHMAD SAJID	Electrical	(02) 665-8420 x 2047
SALEEM AHMAD	Electrical	(03) 586-8600 x 62679
SALEEM BAIG MIRZA	Civil	(01) 477-8384
SALEEM GHOUS KHAN	Miscellaneous	(03) 860-4730
SALMAN M. KHAN	Civil	(03) 874-6859
SALMAN MEHMOOD	Electronics	(03) 857-9922
SALMAN MUSTAFA	Electrical	(03) 566-2072
SAMI UDDIN CHUGHTAI	Mechanical	(03) 868-2255
SAQIB SHAH	Electrical	(01) 464-1188 x 292
SARFRAZ AHMAD MALIK	Mechanical	(03) 357-7236
SARFRAZ MAHMOOD	Electrical	(01) 452-8519
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SHABBIR AHMED BUTT	Architecture	(02) 675-7253
SHABBIR AHMED	Mechanical	(01) 465-9975
SHAH NAWAZ KHAN	Electrical	(07) 227-1111 x 1381
SHAH ZAMAN PANHWAR	Electrical	(02) 660-3672
SHAHABUDDIN	Miscellaneous	(01) 523-5529
SHAHID AKHTAR BUTT	Electrical	(03) 357-7320
SHAHID AKRAM	Electrical	(01) 479-0345 x 4100
SHAHID ANWAR	Civil	(01) 249-9270
SHAHID MASOOD	Mechanical	(03) 572-0059
SHAHID YOUNUS KHAN	Mechanical	(03) 358-4000 x 205
SHAHID ZUBAIR	Electrical	(01) 265-1515 x 507
SHAHZAD ALI BAIG	Electrical	(03) 882-9394
SHAIKH ASRAR AHMED	Electronics	(01) 452-7151
SHAIKH MOHAMMAD	Civil	(01) 472-4338
SHAKEEL AHMAD	Electrical	(01) 402-0227
SHAKIL AHMAD	Electrical	(03) 722-3111 x 73159
SHAKIL OMAR	Electrical	(03) 857-7738
SHAMEEM AHMAD	Mechanical	(03) 343-0333 x 31002
SHAMIM AHMED	Mechanical	(03) 341-0671
SHAMIM ALAM KHAN	Electrical	(01) 403-1128
SHAMIM UDDIN	Mechanical	(01) 464-1188 x 283
SHAMS-UD-DIN AHMED	Mechanical	(03) 340-1606
SHAMS-UR-REHMAN	Mechanical	(01) 230-0567
SHARFUDDIN	Mechanical	(03) 343-0333 x 31002
SHARFUDDIN S. MALIK	Miscellaneous	(01) 465-9975
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SHAUKAT PERVAIZ	Mechanical	(01) 478-4401
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SHEIKH AKHTAR HUSAIN	Civil	(01) 465-9975 x 240
SHEIKH KHALIL AHMED	Civil	(01) 4549191 x 225
SHEIKH MAHMOOD	Electrical	(03) 373-0308 x 72634
SHEIKH MOHAMMAD	Mechanical	(07) 227-1111 x 1124
SHIEKH NISAR	Mechanical	(07) 227-1111 x 1306
SHIRAZ AMJAD	Electrical	(01) 265-3030 x 1594
SHOAIB AHMAD	Electrical	(03) 867-7838
SIKANDER JAVED KHAN	Mechanical	(03) 358-4000 x 414
SIRAJ UL HUDA SIDDIQUI	Mechanical	(01) 464-1188 x 250
SULTAN ALI MANZOOR	Electrical	(03) 858-7075 x 37
SYED ABUL HASAN JAFRI	Electrical	(02) 665 4616
SYED ADNAN ALI	Electronics	(01) 462-9095 x 5313
SYED ADNAN MOID	Electrical	(01) 462-5858 x 248
SYED AFZAL HUSAIN	Electrical	(01) 465-4406
SYED AHMED MAHMOOD	Mechanical	(02) 640-0004 x 378
SYED ALI HAROON	Chemical	(03) 827-1652
SYED AMIR UR REHMAN	Electrical	(03) 835-8875
SYED ANWAR ALI	Mechanical	(03) 857-2300 x 84951
SYED ASHFAQUE	Electronics	(02) 671-7285
SYED ASLAM ALI	Mechanical	(03) 894-6816 x 259
SYED AZHAR MAQSOOD	Civil	(01) 464-1498
SYED FAIZ AHMAD	Civil	(01) 477-3115 x 3845
SYED FARID MUSTAFA	Electrical	(03) 882-5669
SYED GHULAM MUSTAFA	Civil	(01) 454-9191
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SYED ITRAT HUSSAIN	Mechanical	(01) 246-4632
SYED KAFIL AHMED	Mechanical	(03) 566-0600 x 525
SYED KHALID UMER	Mechanical	(01) 452-8211
SYED KHAWAJA NEHAL	Electronics	(01) 495-1300 x 228
SYED KHURSIED ABBAS	Electronics	(04) 396-6176
SYED MANSOOR AHMED	Electrical	(01) 462-2888 / 464-2356
SYED MANZAR HASNAIN	Mechanical	(01) 464-9688

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NAME	DISCIPLINE	PH. (OFFICE)
SYED MASOODUL	Mechanical	(03) 678-8463
SYED MOHAMMAD ALI	Civil	(03) 833-3997
SYED MOHAMMAD IQBAL	Electrical	(01) 452-3252
SYED MOHAMMAD	Electrical	(01) 464-9688
SYED MOHAMMAD	Mechanical	(03) 860-3135
SYED MOHTASHIM NIZAM	Mechanical	(03) 895-5004
SYED MUBASHIR UL	Electrical	(01) 474-0555 x 191
SYED MURSHID PERVEZ	Electrical	(01) 406-9200 x 278
SYED NAEEM ALI	Architecture	(02) 654-7171
SYED NASIR UDDIN	Mechanical	(02) 651-9998 x 235
SYED NAVED HAIDER	Electrical	(03) 882-5669 x 223
SYED NAZEEF AKHTER	Electronics	(01) 454-9191 x 260
SYED NIAZ AHSAN	Metallurgy	(03) 359-9210
SYED RAHEEL AZAM	Electrical	(03) 864-1012
SYED SAFDAR RAZA	Mechanical	(01) 463-1111 x 5182
SYED SAJID HUSSAIN	Mechanical	(01) 401-2550 / 41765816
SYED SALMAN SHAFIQ	Computer	(01) 452-6275
SYED SAMIUDDIN AHMED	Civil	(03) 895-5004 x 242
SYED SHABBIR AHMED	Electrical	(01) 403-2222 x 29716
SYED SHAHERYAR A	Electrical	(01) 401-2550 x 608
SYED SHAMSUL HAQ	Electrical	(01) 472-4238
SYED TASNEEM HUSAIN	Electrical	(01) 265-1689 x 1482
SYED TOUSEEF AHMAD	Electrical	(01) 452-3268
SYED UMER MOIZ	Electrical	(01) 467-2759
SYED WAJID HUSSAIN	Electrical	(03) 858-4855 x 307
SYED WALIULLAH	Mechanical	(02) 667-0092 x 336
SYED WASI IMAM	Civil	(03) 895-5004 x 229
SYED WIQAR FAKHRI	Electrical	(03) 378-3581
SYED ZAFAR AHMAD	Mechanical	(01) 476-9777 x 42310
SYED ZAFAR WAHAB	Electrical	(03) 586-8600 x 62864
SYED ZAHID HASSAN	Electrical	(01) 403-2222 x 3150
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TANWEER EJAZ NAWAZ	Electrical	(03) 858-6725
TANWEER NAWAZ MALIK	Electrical	(01) 478-0777 x 858
TARIQ AHMED SHEIKH	Metallurgy	(07) 227-1111 x 1301
TARIQ BIN ZAFAR	Mechanical	(03) 859-0484
TARIQ MAHMOOD	Chemical	(01) 498-4000 x 1888
TARIQ MUMTAZ SOOMRO	Electrical	(01) 293-3617 / 464-3082
TARIQ MUSHTAQ	Electrical	(03) 858-5471
TASADDUQ HUSSAIN	Electronics	(01) 206-0000 x 3334
TASNEEM AHMED	Electronics	(03) 858-7505 / 858-7595
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WAHEED AKHTER	Electronics	(01) 464-9811 x 430
WAJAHAT HUSSAIN	Electrical	(02) 640-0004 x 265
WAQAR AHMAD	Mechanical	(01) 465-9975 x 219
WAQAR USMAN MIAN	Metallurgy	(03) 832-4400 x 564
WASEEM NOOR MALIK	Civil	(01) 454-9191 x 224
WAZIR ULLAH KHAN	Electrical	(03) 889-1609
YASER MAHMOOD	Electrical	(01) 403-2222 x 1225
ZAFAR AHMED TALPUR	Mechanical	(02) 691-6240
ZAFARULLAH KHAN DR.	Mechanical	(03) 860-2693
ZAHEER UDDIN AHMAD	Mechanical	(01) 498-2807 x 455/ 498-
ZAHID KHAN	Electronics	(07) 227-1111 x 1410
ZAINULABDIN PATHAN	Civil	(01) 403-2222 x 29758
ZAKIR RAZA	Electrical	(01) 477-7000
ZUBAIR AHMED	Electrical	(01) 465-6975
ZUBAIR AKHTAR	Mechanical	(01) 463-1111 x 2805
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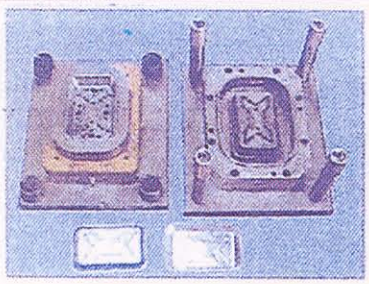

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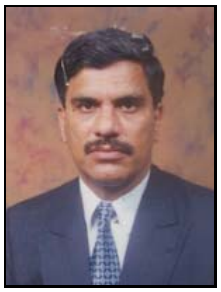

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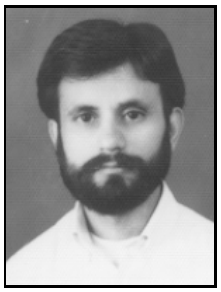

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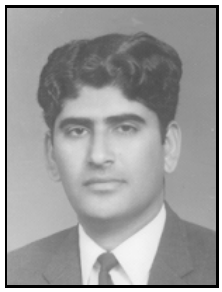

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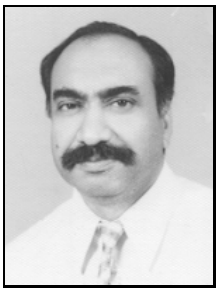

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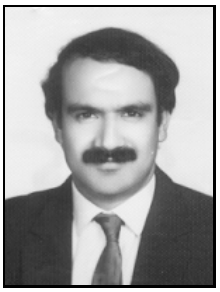

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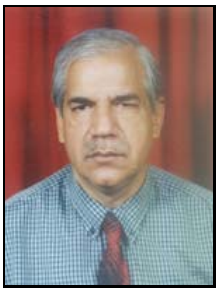

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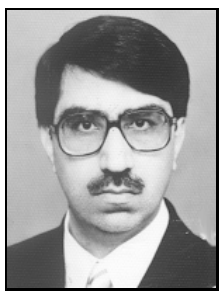

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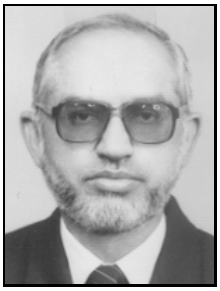

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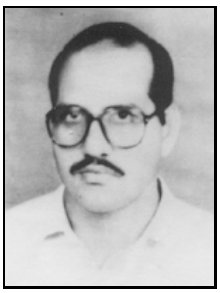

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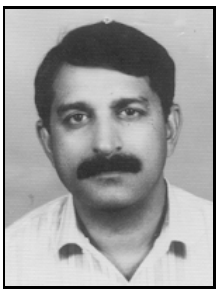

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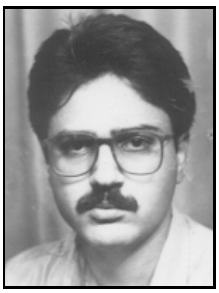

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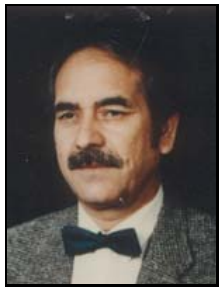

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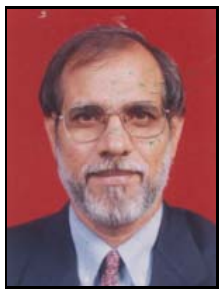

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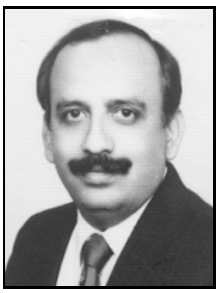

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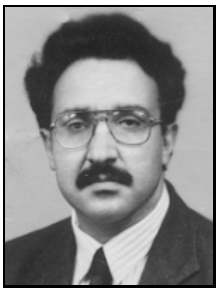

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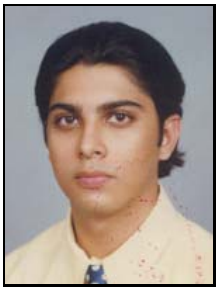

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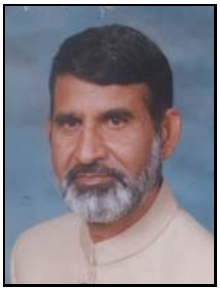

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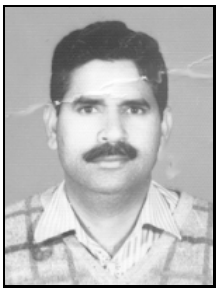

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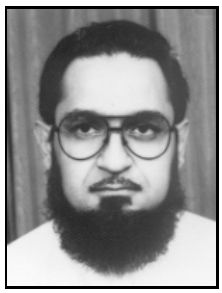

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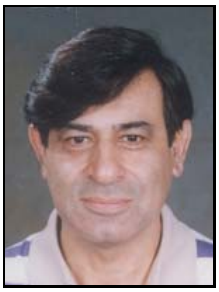

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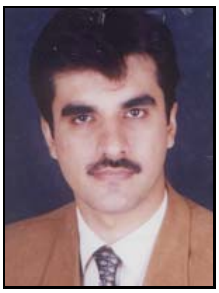

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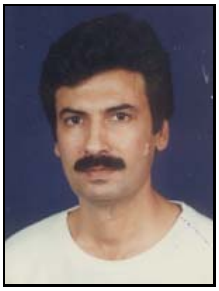

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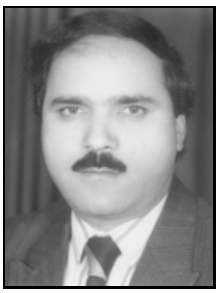

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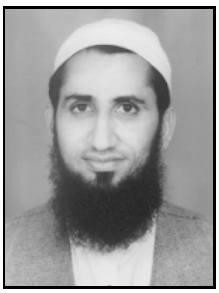

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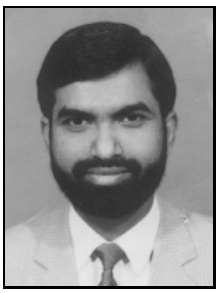

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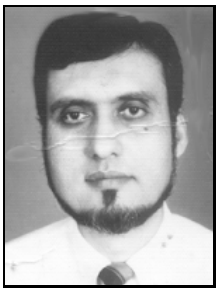

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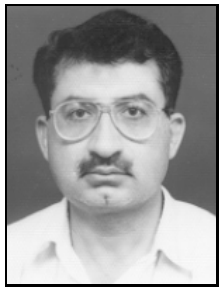

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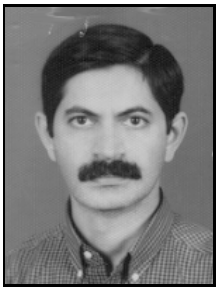

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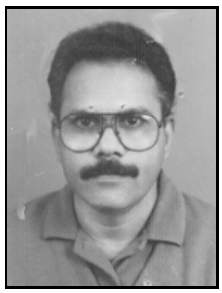

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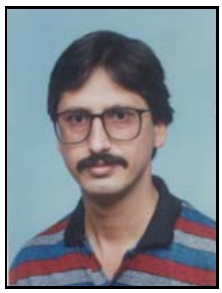

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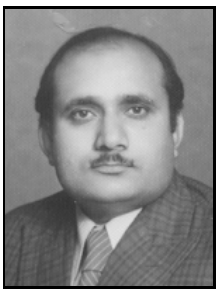

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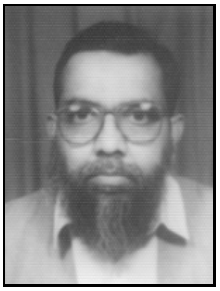

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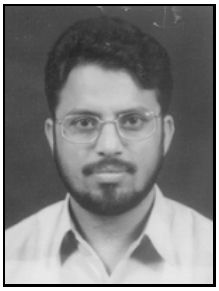

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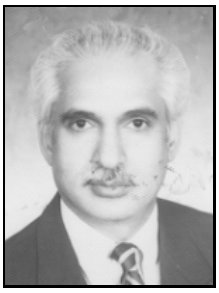

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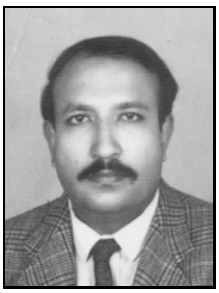

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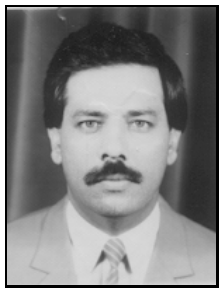

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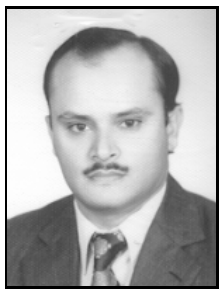

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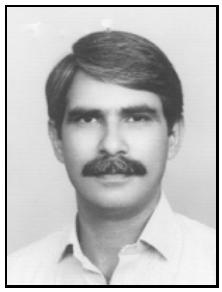

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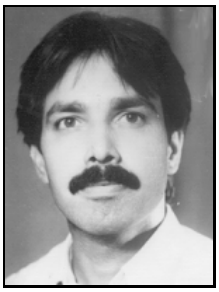

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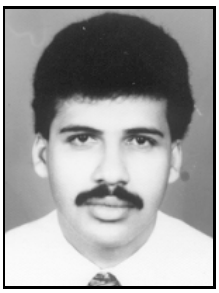

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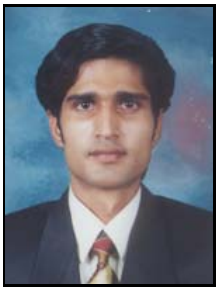

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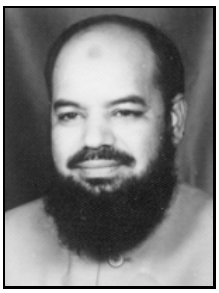

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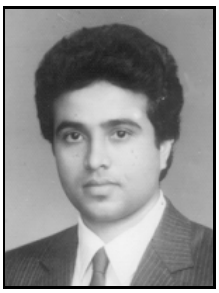

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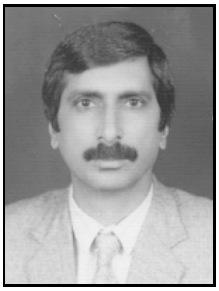

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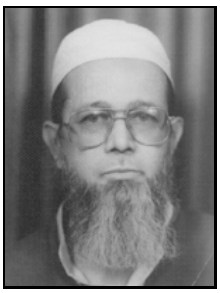

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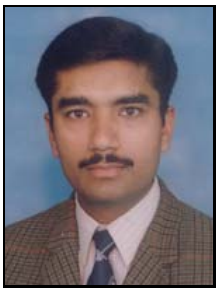

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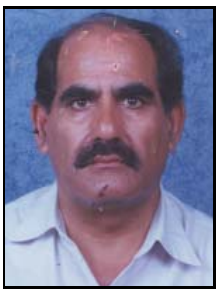

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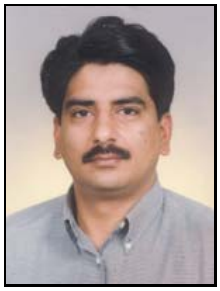

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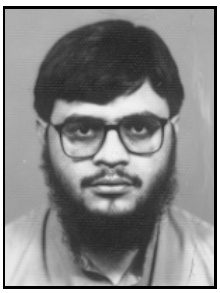

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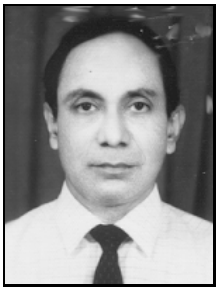

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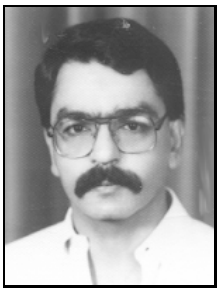

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ACRONYM AND ABBREVIATIONS

AE	Associate Engineer
AEC	Ahsanullah Engineering College, Dacca
Aero	Aeronautical Engineering
Agr	Agricultural
AIT	Asian Institute of Technology, Bangkok, Thailand
AMU	Aligarh Muslim University, India
AUB	Astonton University, Birmingham
AUUP	Allahabad University, UP, India
BCE	Bihar College of Engineering
BU	Baluchistan University, Pakistan
BUE	Birmingham University, England
CBA	College of Business Administration, Lahore
CE	Civil Engineering
CEI	Council of Engineering Institution, UK
CET	College of Engineering, Taxila, Pakistan
Chem	Chemical Engineering
CMSU	Central Missouri State University, USA
Comp	Computer
CPU	California Pacific University, USA
CSU	California State University, USA
DCET	Dawood College of Engineering & Technology, Karachi, Pakistan
DIT	Detroit Institute of Technology, USA
DU	Duke University, USA
DUP	Drexel University, Philadelphia, USA
E	Electrical
Ecs	Electronics
Env	Environmental
EE	Electrical Engineering
EPUET	East Pakistan University of Engineering & Technology, Dacca
ET	ENSAE Toulouse, France
GCTK	Govt. College of Technology, Karachi
GIK	G. I. K. Institute of Engineering and Technology, Topi, Pakistan
GPIS	Govt. Polytechnic Institute, Sialkot, Pakistan
GT	Georgia Tech, USA
GWU	George Washington University, USA
HP	Huddersfield Polytechnic, UK
HWU	Heroit Watt University Edinburg, UK
IBA	Institute of Business Administration, Karachi
ICES	Institute of Civil Engineering Surveyors, UK
ICUL	Imperial College University of London, UK
IEEL	Institution of Electrical Engineers London, UK
IEP	Institution of Engineers Pakistan Exam Section A&B
IIT	Illinois Institute of Technology, Chicago, USA
Ind	Industrial
IQA	Institution of Quality Assurance, UK
IU	International University
KCL	King's College London, UK
KFUPM	King Fahad University of Petroleum & Minerals, Dhahran, Saudi Arabia
KFUPM-RI	King Fahad University of Petroleum & Minerals-Research Institute
KU	Karachi University, Pakistan
KWU	Kennedy Western University, USA
LP	Liverpool Polytechnic
LU	Lamar University, Texas, USA
M.E.	Master of Engineering
M.S.	Master of Science
ME	Mechanical Engineering
MEH	Mehran Engineering University, Jamshoro
Met	Metallurgical Engineering
METU	Middle East Technical University, Ankara, Turkey
Min	Mining
MiSU	Mississippi State University, USA
MMU	Manchester Metropolitan University, UK
MOPTT	Ministry of Post, Telegraph and Telephone, Saudi Arabia
MSU	Michigan State University, USA
MTU	Michigan Technology University, USA
MUET	Mehran University of Engineering & Technology, Jamshoro
NCA	National College of Arts, Lahore
NCET	National College of Engg. & Technology, Karachi, Pakistan
NED	NED College/University of Engineering & Technology, Karachi
NEU	Near East University
NU	Northrop University, USA
Nuc	Nuclear Engineering
NWFPUET	North West Frontier Province Uni. of Engg. & Tech., Peshawar, Pakistan
Off.	Office
OSU	Ohio State University
OU	Osmania University, Hyderabad
OUM	Oakland University, Michigan, USA
PAFCAE	Pakistan Air Force College of Aeronautical Engineering, Karachi
PCET	Punjab College of Engineering & Technology, Lahore
PCOA	Pakistan College of Aeronautical Engineering
PE	Petroleum Engineering
Pet	Petroleum
PGC	Post Graduate Course
PGD	Post Graduate Diploma
PIBR	Polytechnic Institute Bucharest, Rumania
PINSTC	Pakistan Institute of Science & Technology, Islamabad
PNEC	Pakistan Navy Engineering College
PSU	Penn. State University, USA
PU	Punjab University, Lahore
PUI	Purdue University, West Lafayette, Indiana, USA
PUK	Preston University, Karachi, Pakistan
QAU	Quaid-e-Azam University Islamabad
Res.	Residence

RU	Ranchi University, India
RUH	Rice University Huston, USA
S	Systems
SGW	Sir George Williams, Canada
SIU	Southern Illinois University, USA
Sr.	Senior
SSUET	Sir Syed University of Engineering and Technology, Karachi, Pakistan
SU	Sind University, Jamshoro, Pakistan
SUC	Stanford University, California, USA
TSC	Telecom. Staff College, Haripur, Pakistan
TUB	Technical University, Berlin, Germany
U	University
UB	University of Bahrain
UD	University of Detroit, Michigan, USA
UDE	University of Durham, England
UETL	University of Engineering and Technology, Lahore, Pakistan
UL	University of Leeds, UK
UM	University of Michigan, Ann Arber, USA
UNSW	University of New South Wales, Australia
UOB	University of Bradford, UK
UOBE	University of Birmingham, UK
UOC	University of California, USA
UOD	University of Detroit, Michigan, USA
UOF	University of Florida, USA
UOG	University of Glasgow, UK
UOI	University of Illinois, Urbana, USA
UOL	University of London
UOM	University of Manchester, UK
UOM	University of Minisotta, USA
UON	University of Nottingham, UK
UOP	University of Peshawar, Pakistan
UOS	University of Salford, UK
UOT	University of Engineering and Technology, Taxila
UOW	University of Waterloo, Canada
UPM	University of Petroleum & Minerals, Dhahran, Saudi Arabia
US	University of Southampton, UK
USC	University of Southern California, Los Angeles, USA
UTA	University of Texas, Austin, USA
UTC	University of Toronto, Canada
UW	University of Windsor, Ontario, Canada
WSU	Washington State University, USA
WU	Winconsin University, USA
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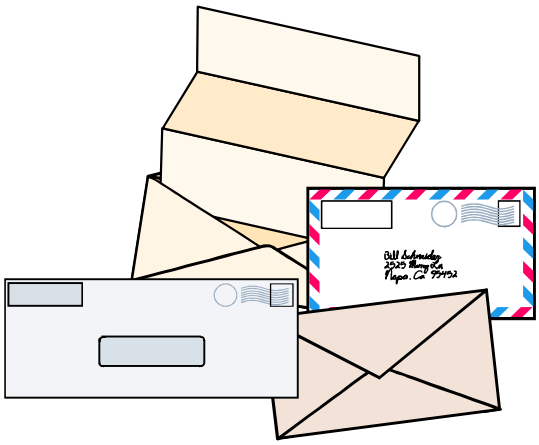

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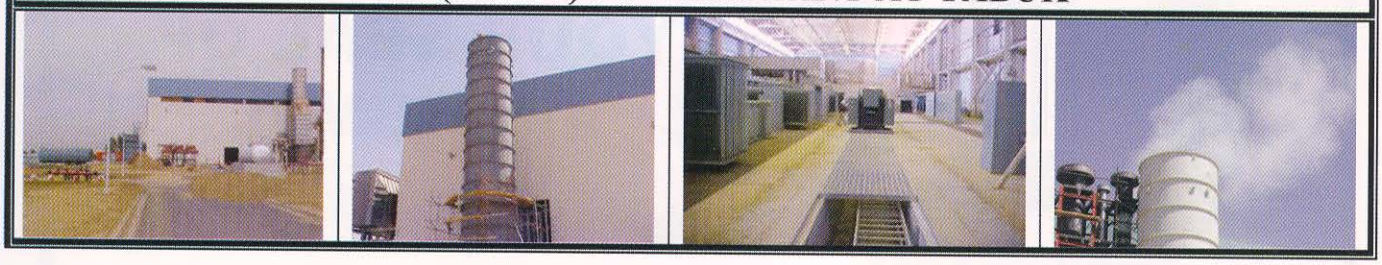

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A SYMBOL OF PRIDE FOR PAKISTAN

Modern fighter aircraft are the most essential and effective components of air power. It is believed that in any future conflict in our region, the side which has the dominance in air power, will not only dominate the battlefield to win the war, but also cause extensive destruction of the enemy's military communication and industrial infrastructure. Considering our past experiences and the economic constraints, PAF with the co-operation of a Chinese company, embarked upon the insurmountable task of producing a modem fighter aircraft indigenously.

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The JF-17 is a low cost, new generation, multi-role, lightweight fighter aircraft. It has the capability to perform extremely well in air defense as well as surface attack roles. An efficient man-machine-interface, high situation awareness, effective firepower and combat survivability are the hallmarks of this aircraft. With its state of the art avionics, highly advanced sub-systems, computerized flying controls and latest weapon systems, the aircraft will out fight the fighters of its own class. On the whole, JF-17 is a potent weapon system, which would offer significant capabilities to any Air Force. In today's world, there is no aircraft in this class of fighters that can provide such enviable capabilities and that too at such a low cost.

RECOGNIZED ENGINEERING QUALIFICATIONS

Following Engineering Programs of various Universities/Institutions in Pakistan are accredited with Pakistan Engineering Council (PEC):

PUNJAB

1. **University of Engineering and Technology, Lahore (http://www.uet.edu.pk/)**
   - B.Sc. Engineering (Civil, Electrical, Mechanical, Chemical, Metallurgical, Mining and Petro-Gas and Industrial & Manufacturing Engineering).
2. **Institute of Chemical Engineering and Technology, Lahore (University of Punjab)**
   - B.Sc. Engineering (Chemical, Metallurgy & Materials Science)
3. **University of Agriculture, Faisalabad (http://www.uaf.edu.pk/)**
   - B.Sc. Engineering (Agricultural). Accreditation expired in the year 2003. Re-accreditation is under process.
4. **NFC Institute of Engineering and Technological Training, Multan (Bahauddin Zakariya University)**
   - B.Sc. Engineering (Chemical). Accreditation expired in the year 2003. Re-accreditation is pending due to deficiencies.
5. **College of Electrical & Mechanical, Rawalpindi (NUST) (http://www.nust.edu.pk/)**
   - B.E. (Electrical and Mechanical and Computer)
   - B.E. (Mechatronics). Re-accreditation is under process.
6. **Military College of Signals, Rawalpindi (NUST) (http://www.nust.edu.pk/)**
   - B.E. Electrical (Communication) and Computer Software.
7. **University of Engineering and Technology, Taxila (http://www.uettaxila.edu.pk/)**
   - B.Sc. Engineering (Civil, Electrical and Mechanical)
   - B.Sc. Engineering (Computer). Accreditation is under process.
8. **University College of Engineering and Technology, Multan (Bahauddin Zakariya University)**
   - B.Sc. (Civil Engineering and Electrical Engineering). Re-accreditation is due in 2004.
9. **National College of Textile Engineering, Faisalabad (UET Lahore)**
   - B.Sc. (Textile Engineering)
10. **NFC, Institute of Engineering & Fertilizer Research, Faisalabad (UET Lahore)**
    - B.Sc. (Chemical Engineering).
11. **Islamic International Engineering College, Islamabad (UET Taxila)**
    - B.Sc. Electrical Engineering (Communication) w.e.f. the Intake Year 1998 subject to review in 2004.
12. **COMSATS Institute of Information Technology (Jauhar Campus), Islamabad (http://www.ciit.edu.pk/)**
    - B.Sc. Computer Engineering w.e.f. the Intake Year 1999 subject to review in 2004.

SINDH

1. **NED University of Engineering and Technology, Karachi (http://www.neduet.edu.pk/)**
   - B.E. (Civil, Electrical, Mechanical, Electronics and Industrial & Manufacturing)
   - B.E. (Computer Systems and Textile). Re-accredited for one year, will be revisited in 2005.
2. **Institute of Industrial Electronics Engineering (PCSIR), Karachi (NED UET)**
   - B.E. (Industrial Electronics)
3. **Mehran University of Engineering and Technology, Jamshoro (http://www.muet.edu.pk/)**
   - B.E. (Civil, Electrical, Mechanical, Metallurgical, Computer Systems and Chemical)
   - B.E (Electronics, Mining, Industrial, Textile and Petrogas) Re-accredited for one year.
4. **Usman Institute of Technology, Karachi (Hamdard University) (http://www.uit.edu/)**
   - B.E. (Electronics and Computer Systems). Re-accreditation is due in 2004.
5. **Sir Syed University of Engineering & Technology, Karachi (http://www.ssuet.edu.pk/)**
   - B.S. (Civil, Electronics, Bio-Medical and Computer Engineering)

6. **Pakistan Navy Engineering College, Karachi (NUST) (http://www.nust.edu.pk/)**
   - B.E. (Electrical and Mechanical)
7. **Quaid-e-Awam University of Engineering, Science & Technology, Nawabshah (http://www.quest.edu.pk/)**
   - B.E. (Civil, Electrical, Mechanical).
   - B.E. (Computer Systems). Accreditation expired in 2003. Re-accreditation is pending due to deficiencies.
8. **Sindh Agriculture University, Tandojam (http://www.sau.edu.pk/)**
   - B.E. (Agricultural).

NWFP

1. **NWFP University of Engineering & Technology, Peshawar (http://www.nwfpuet.edu.pk/)**
   - B.Sc. Engineering (Civil, Electrical, Mechanical, Mining and Agriculture)
   - Re-accreditation of B.Sc. Engineering (Chemical) is under process.
   - B.Sc. Computer Information Systems Engineering w.e.f. Intake Year 1999 subject to review in 2004.
2. **College of Aeronautical Engineering, Risalpur (NUST) (http://www.nust.edu.pk/)**
   - B.E. (Aerospace and Avionics)
3. **Military College of Engineering, Risalpur (NUST) (http://www.nust.edu.pk/)**
   - B.E. Civil.
4. **Ghulam Ishaque Khan Institute of Engineering Sciences & Technology, Topi, Swabi (http://www.giki.edu.pk/)**
   - B.Sc. Engineering (Mechanical, Electronics, Metallurgy & Material, Computer System)
   - B.Sc. Engineering (Engineering Sciences with majors in Modeling & Simulation, or Laser & Opto Electronics or Semi Conductors & Super Conducting Devices).
5. **CECOS University of Information Technology and Emerging Sciences, Peshawar (http://www.cecos.edu.pk/)**
   - B.Sc. Civil Engineering w.e.f. the Intake year 2002 subject to review in year 2004.
   - B.Sc. Electrical Engineering w.e.f. the Intake year 2002 subject to review in the year 2004.
6. **Peshawar College of Engineering, Peshawar (NWFP UET)**
   - B.Sc. Electrical Engineering. w.e.f. the Intake year 1999 subject to review in year 2004.

BALOCHISTAN

1. **Balochistan University of Engineering & Technology, Khuzdar**
   - B.E. (Civil, Electrical and Mechanical). Accreditation expired in 2002. Re-accreditation is under process.

AJ&K

1. **Ali Ahmed Shah, University College of Engineering & Technology, Mirpur (AJ&K)**
   - B.Sc. (Electrical Engineering). Accreditation expired in 2003. Re-accreditation is pending due to deficiencies.

CHARTERED UNIVERSITIES / DEGREE AWARDING INSTITUTES
IN PUBLIC SECTOR

	CHARTERED UNIVERSITY / DEGREE AWARDING INSTITUTE	ESTABLISHED ON
1.	Air University, Islamabad (http://www.au.edu.pk)	29th Oct 2002
2.	Allama Iqbal Open University, Islamabad (http://www.aiou.edu.pk)	25th May 1974
3.	Bahauddin Zakariya University, Multan (http://www.bzu.edu.pk)	4th Mar 1975
4.	Bahria University, Islamabad (http://www.bci.edu.pk)	7th Feb 2000
5.	Balochistan University of Engineering and Technology, Khuzdar (http://www.wb.sdnpk.org/buet)	3rd Aug 1994
6.	Balochistan University of Info. Technology and Man. Sciences, Quetta (http://www.buitms.edu.pk)	18th Jul 2002
7.	COMSATS Institute of Information Technology, Islamabad (http://www.ciit.edu.pk)	12th Aug 2000
8.	Dow University of Health Sciences Karachi (http://www.dumhs.com)	29th Dec 2003
9.	Fatima Jinnah Women University, Rawalpindi (http://www.fjwu.edu.pk)	5th Aug 1998
10.	Federal Urdu University of Arts, Sciences and Technology, Islamabad (http://www.fuuast.edu.pk)	13th Nov 2002
11.	Gomal University, D.I. Khan (http://www.gu.edu.pk)	2nd Dec 1974
12.	Government College University, Faisalabad	19th Oct 2002
13.	Government College University, Lahore (http://www.gcu.edu.pk)	16th Jun 1997
14.	Hazara University, Dodhial, Mansehra (http://www.hu.edu.pk)	Oct 2001
15.	Institute of Business Administration, Karachi (http://www.iba.edu.pk)	17th Aug 1994
16.	Institute of Management Sciences, Peshawar (http://www.ims.net.pk)	2nd Oct 2002
17.	International Islamic University, Islamabad (http://www.iiu.edu.pk)	26th Nov 1980
18.	Islamia University, Bahawalpur	4th Mar 1975
19.	Karakuram International University, Gilgit	27th Aug 2002
20.	Kinnaird College for Women, Lahore	25th Oct 2002
21.	Kohat University of Science & Technology, Kohat (http://www.kust.edu.pk)	31st Aug 2001
22.	Lahore College for Women University, Lahore (http://www.lcwu.edu.pk)	27th Aug 1999
23.	Liaquat University of Medical and Health Sciences, Jamshoro (http://www.lumhs.edu.pk)	20th Jan 2001
24.	Mehran University of Engineering and Technology, Jamshoro (http://www.muet.edu.pk)	30th May 1977
25.	National College of Arts, Lahore (http://www.nca.edu.pk)	31st Mar 1985
26.	National University of Modern Languages, Islamabad (http://www.numl.edu.pk)	29th May 2000
27.	National University of Sciences & Technology, Rawalpindi (http://www.nust.edu.pk)	13th Mar 1993
28.	NED University of Engineering & Technology, Karachi (http://www.neduet.edu.pk)	30th May 1977
29.	NWFP Agriculture University, Peshawar (http://www.aup.edu.pk)	4th Feb 1981
30.	NWFP University of Engineering & Technology, Peshawar (http://www.nwfpuetp.edu.pk)	23rd Oct 1980
31.	Pakistan Institute of Engineering & Applied Sciences, Islamabad (http://www.pieas.edu.pk)	22nd Mar 2000
32.	Pakistan Military Academy, Kakul, Abbottabad	1959
33.	Pakistan Naval Academy, Karachi (http://www.paknavy.gov.pk/training/index.html)	12th Nov 1965
34.	Quaid-i-Azam University, Islamabad (http://www.qau.edu.pk)	May 1965
35.	Quaid-e-Awam University of Engineering, Science & Tech., Nawabshah (http://www.quest.edu.pk)	7th Aug 1996
36.	Sardar Bahadur Khan Women University, Quetta	11th Mar 2004
37.	Shah Abdul Latif University, Khairpur (http://www.salu.edu.pk)	8th Dec 1986
38.	Sindh Agriculture University, Tandojam (http://www.sau.edu.pk)	30th May 1977
39.	University of Agriculture, Faisalabad (http://www.uaf.edu.pk)	1st Nov 1961
40.	University of Arid Agriculture, Rawalpindi (http://www.uaar.edu.pk)	24th May 1995
41.	University of Azad Jammu & Kashmir, Muzaffarabad, Azad Kashmir	22nd Jul 1980
42.	University of Balochistan, Quetta (http://uob.cjb.net)	1970
43.	University of Education, Lahore	10th Sep 2002
44.	University of Engineering & Technology, Lahore (http://www.uet.edu.pk)	1961
45.	University of Engineering & Technology, Taxila (http://www.uettaxila.edu.pk)	10th Oct 1993
46.	University of Health Sciences, Lahore	28th Sep 2002
47.	University of Karachi, Karachi (http://www.ku.edu.pk)	June 1951
48.	University of Malakand, Chakdara, Dir. Malakand	27th Oct 2001
49.	University of Peshawar, Peshawar (http://www.upesh.edu)	30th Oct 1950
50.	University of Sargodha, Sargodha	16th Nov 2002
51.	University of Sindh, Jamshoro (http://www.usindh.edu.pk)	1947
52.	University of the Punjab, Lahore (http://www.pu.edu.pk)	1882
53.	University of Veterinary and Animal Sciences, Lahore	8th Jun 2002
54.	Virtual University of Pakistan, Lahore (http://www.vu.edu.pk)	11th Sep 2002
55.	University of Gujrat , Gujrat	25th Feb 2004

Total 47 Chartered Universities and 8 Degree Awarding Institutes in Public Sector

CHARTERED UNIVERSITIES / DEGREE AWARDING INSTITUTES
IN PRIVATE SECTOR

	CHARTERED UNIVERSITY / DEGREE AWARDING INSTITUTE	ESTABLISHED ON
1.	Agha Khan University, Karachi (http://www.akuweb.com)	2nd Mar 1983
2.	Al-Khair University, Mirpur, Azad Kashmir	11th Jul 1994
3.	Baqai Medical University, Karachi	26th May 1996
4.	CECOS University of Info. Technology and Emerging Sciences, Peshawar (http://www.cecos.com)	30th Aug 2001
5.	City University of Science & Information Technology, Peshawar (http://www.cityuniversity.edu.pk)	30th Aug 2001
6.	Dadabhoy Institute of Higher Education, Karachi	12th Jan 2004
7.	Forman Christian College, Lahore	12th Oct 2004
8.	Foundation University, Islamabad	25th Oct 2002
9.	Gandhara University, Peshawar (http://www.gandhara.edu.pk)	23rd Nov 2002
10.	Ghulam Ishaq Khan Institute of Engineering Sci. & Technology, Swabi (http://www.giki.edu.pk)	18th Jul 1994
11.	Gift University, Gujranwala (http://www.gift.edu.pk)	10th Jun 2004
12.	Greenwich University, Karachi (http://www.greenwichuniversity.edu.pk)	3rd Feb 1998
13	Hajvery University, Lahore (http://www.hajvery.edu.pk)	2nd Oct 2002
14.	Hamdard University, Karachi (http://www.hamdard.edu.pk)	22nd Feb 1992
15.	Imperial College of Business Studies, Lahore (http://www.imperial.edu.pk)	10th Apr 2002
16.	Indus Valley School of Art and Architecture, Karachi (http://www.indusvalley.edu.pk)	27th Jul 1994
17.	Institute of Business Management, Karachi (http://www.cbm.edu.pk)	27th Apr 1998
18.	Institute of Business & Technology BIZTEK, Karachi	12th Jan 2004
19.	Institute of Management Sciences, Lahore (http://www.pakaims.edu.pk)	10th Apr 2002
20.	Institute of South Asia, Lahore	27th Jul 2003
21.	Iqra University, Karachi (http://www.iqra.edu.pk)	21st Jun 2000
22.	Iqra University, Quetta (http://www.iqra.edu.pk)	2nd Nov 2002
23.	Isra University, Hyderabad (http://www.isra.edu.pk)	27th Sep 1997
24.	Jinnah University for Women, Karachi (http://www.juw.edu.pk)	2nd Jun 1998
25.	Karachi Institute of Economics & Technology, Karachi	24th May 2000
26.	KASB (Khadim Ali Shah Bukhari) Institute of Technology, Karachi (http://www.kasbit.edu.pk)	28th Jun 2001
27.	Lahore School of Economics, Lahore (http://www.lse.edu.pk)	8th Jan 1997
28.	Lahore University of Management Sciences, Lahore (http://www.lums.edu.pk)	31st Mar 1985
29.	Mohammad Ali Jinnah University, Karachi	1st Jul 1998
30.	Mohi-ud-Din Islamic University, Nerian Sharif, Azad Kashmir (http://www.miu.edu.pk)	18th Jan 2000
31.	National College of Business Admin. & Economics (NCBA&E) Lahore (http://www.ncbae.edu.pk)	10th Apr 2002
32.	National Textile University, Faisalabad	15th Nov 2002
33.	National University of Computer and Emerging Sciences, Islamabad (http://www.nu.edu.pk)	1st Jul 2000
34.	Newports Institute of Communications and Economics, Karachi (http://www.newports.edu.pk)	30th May 2002
35.	Northern University, Nowshera Cantonment	2nd Nov 2002
36.	Preston Institute of Management Sciences and Technology, Karachi	31st Jul 2001
37.	Preston University, Kohat	23rd Nov 2002
38.	Preston University, Karachi	18th Feb 2004
39.	Qurtaba University of Science & Information Technology, D. I. Khan (http://www.qurtuba.edu.pk)	30th Aug 2001
40.	Riphah International University, Islamabad (http://www.riu.edu.pk)	16th Oct 2002
41.	Sarhad University of Science & Information Technology, Peshawar (http://www.suit.edu.pk)	30th Aug 2001
42.	Shaheed Zulfikar Ali Bhutto Institute of Science & Technology (SZABIST), Karachi (http://www.szabist.edu.pk)	25th Oct 1995
43.	Sir Syed University of Engineering. & Technology, Karachi (http://www.ssuet.edu.pk)	25th Oct 1995
44.	Textile Institute of Pakistan, Karachi (http://www.tip.edu.pk)	21st Apr 2001
45.	The Superior College, Lahore	16th Jun 2004
46.	The University of Management & Technology, Lahore (http://www.umt.edu.pk/index.htm)	16th Jun 2004
47.	University of Central Punjab, Lahore (http://www.ucp.edu.pk)	10th Apr 2002
48.	University of Faisalabad, Faisalabad (http://www.tuf.edu.pk)	2nd Oct 2002
49.	University of Lahore, Thokar Niaz Baig, Lahore	2nd Oct 2002
50.	Zia-ud-Din Medical University, Karachi	8th Oct 1995

Total 34 Chartered Universities and 16 Degree Awarding Institutes in Private Sector

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