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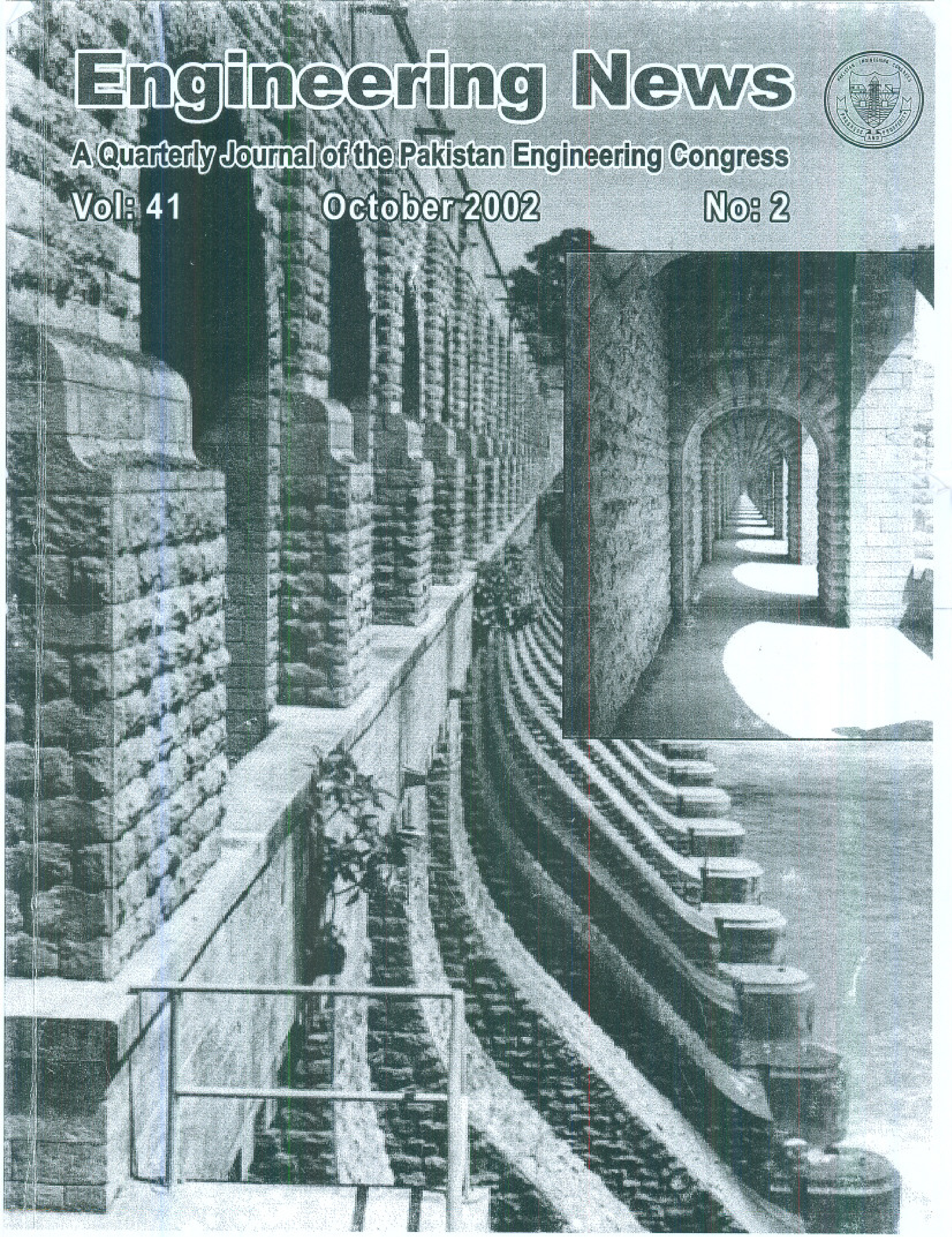

COVER PHOTO

A beautiful example of civil engineering works national heritage.

Upper Jehlum Canal Head Works located on River Jehlum immediately down stream of Mangala Dam Project . It was constructed using the locally available materials during the early period of the last century. Structures like this one are rare and every effort should be made to preserve and document them for our future generations and world at large. As a matter of fact this structure can go on the list of world heritage if it is duly project at international forum.

Photo and statement on the cover with the courtesy of **Engr. A. W. Mir.**

44th YEAR OF PUBLICATION

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ON OTHER PAGES

IN THIS ISSUE

EDITORIAL

NEWS

TECHNICAL VIEWS

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EDITORIAL

WATER CONSERVATION AND ROLE OF ENGINEERS

The most vehement need for sustenance of life after Air is Water. While Almighty Allah provided Air without let or hindrance, it is not the case with Water. It is available on the ground sparsely in the streams or rivers. Under surface it is not always fit for human consumption or is not economically viable to mine. Little wonder the primitive human beings, devoid of the technology knowledge to fully avail of the existing water resources, had to have their dwellings at the banks of the rivers.

Over the centuries, water resources at the river sides dwindled to cater for the needs of the ever increasing population and urged the humans to explore countryside for food and water for their very existence. It was for this reason that old civilizations of Mesopotamia, Roma and Egypt built water channels to take water along from the rivers to the countryside for its use for growing food and for drinking purposes. The theory of engineering hydraulics designs of that era is not available but remnants of their works of water channels, arched bridges and aqueducts can be seen even these days. Thus the engineers of those eras rose to the occasion and contributed their technical knowledge to help in the sustenance of humanity.

As the population of the world has astronomically exploded and has taken such serious proportions that with all the ultra modern technological knowledge water scarcity is abysmically threatening the existence of life on earth.

It is rightly apprehended that the future global wars would centre around water disputes. It, therefore, becomes incumbent upon engineers of the present day to devise engineering ways and means for the conservation of the available water resources, so as to assure its perennial supplies to every nook and corner of the country by planning, designing and constructing new dams, barrages and distribution infrastructure and urging the Government to take un-prejudiced and un-biased decisions in this respect. It is high time we, engineers, take upon ourselves to rise to the occasion and absolve ourselves of our obligations to the posterity who otherwise will be doomed to extinction on this count alone and the present generation will alone be responsible for resultant catastrophic situations.

Pakistan in endowed with blessings of the Almighty and if we rightly tap the available water resources, we can leave a boon for the posterity to be proud of.

WELCOME TO NEW MEMBERS

The Executive Council of the Pakistan Engineering Congress approved Membership of the following new members in to the Congress fold. The Engineering News congratulates all of them and welcomes to PEC

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HYDRAULIC ENGINEERING THROUGH THE AGES

By

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Like any other achievement of man the science of hydraulic engineering passed through all the evolutionary stages of human intellect. After air, water is the next most vital element to human life. It was, therefore, quite natural that human associations with it should date back to the remotest past. However, primitive man depended upon water to the extent of its availability for drinking purposes only. The early civilizations flourished in locations where water was readily available. As their numbers multiplied and their customary food became either difficult to obtain or very scarce, man looked for alternative sources of sustenance. These were wild grains. Agriculture was accidentally discovered when he found that certain grains he used for food appeared every year on the land close to his dwellings. The discovery that these grains could not be grown without water must have come quite late. It is perhaps this discovery which originated the science of hydraulic engineering. From a primitive origin it has reached a sophisticated level giving birth to many off-springs, such as aeronautics, public health etc, etc. The following few pages give a brief narrative of its evolution.

The Early Works and their Engineers

Since the dawn of human existence, man has been occupied with procurement of food in greater and greater quantities. Primitive agriculture was practised about 5000 B. C. Irrigation was introduced by ancient Egyptians in 4000 B. C. and in the Indus Valley and China it was practised in 2000 B. C. Presumably man's first experience of hydraulic engineering dates back to these periods. No trace of these early irrigation works is existing but the civilizations of the Nile, Mespotamia, the Indus and China could not have existed without a canal system. Irrigation systems were built and rebuilt, destroyed or abandoned depending upon the state of the society which they served, and had profound influence on it. In ancient times, the Mespotamians are said to have relapsed into a state of nomadic herdsmanship after the collapse of their irrigation system. It is remarked by historians that the collapse of the excellent irrigation system in Ceylon (thus converting vast areas into marshes) and of the drainage reclamation works in ancient Greece caused epidemic of malaria leading to practical ruination of the population. Since ancient times, man has been building hydraulic works required for agriculture, water supply to towns, and works for navigation, such as harbours and waterways. In the year 2000 B. C. the Egyptians are said to have built a canal from the delta of the Nile towards the Isthumus of Suez in order to reach the trade routes of the east. The canal was re-commissioned in the time of Darius in the 4th Century B. C. Nearly 4000 years later, a canal from the Nile to Suez was rebuilt by the Suez Canal Company for construction of the Waterway.

In the 14th Century B. C. (the century of Moses birth), Rameses II built irrigation works in Egypt. No traces of them are now visible. In 725 B. C. an aquaduct existed to feed the pool of Siloan. The art of conveying water from one place to another was mastered in such early times and was passed on from the very ancients to the ancient Greeks. From the 5th Century B. C. till the birth of Christ, many milestones mark the intellectual growth of man. Great philosophers like Aristotle and Plato, mathematicians like Euclid and Archemides and great spiritual teachers like Budha and Confucius laid the foundations of Greek, Roman and the eastern civilizations. The scientific bent is apparent in the Greek mind since that century as is demonstrated by founding mathematics on logic, postulating various hypotheses on the structure of matter (including the atomic structure) and a practical application of the discoveries of the time to the service of the community. The Greeks developed an excellent system of water supply, bringing water from long distance through underground ducts. Some of these ducts were equipped with pressure pipes. As a monument to the excellent workmanship of the Greeks some of these ducts are in service even to-day. They built harbours and in many cases connected small islands with the coast by means of causeways thus creating two harbours, the specific examples of which are Portus Aegypiticus and Portus Sidonicus. The Greek having pioneered practical hydraulic engineering passed on the science to their mighty successors, the Romans. It was in the Roman period that some of the most amazing hydraulic works were built.

Excepting Roman Law, the Romans are said to have made little intellectual or philosophical contribution to human knowledge. Whereas in the realm of philosophy and fine arts the Romans could not equal their brilliant predecessors, the Greeks, in the practical field of Engineering and Administration, only the moderns have excelled them. The vast and mighty empire required excellent communications and they took Road Engineering to an enviable zenith. The big cities that emerged with the empire faced many problems of urban engineering, which the Romans successfully tackled. Besides many more features of engineering that the Romans mastered they were the first to fully utilize the great potentials of the arch. The arch was invented in the times of the Assyrian civilization but its great potentiality as an engineering structure was developed by the Romans. At the time of emperor Tiberius (A. D. 35) the city of Rome was supplied with water, the estimates of which vary between 60 to 180 million gallons a day. To supply Rome with this enormous quantity, the Romans built 10 channels with an aggregate length of 250 miles, out of which 30 miles were supported by arched structure. The remains of these excellent structures can be seen to-day. Yet another example of the Roman skill in the field of hydraulic engineering was the drainage of lake Fucino in the time of Emperor Clauduis (A. D. 50). To provide an outlet for the lake, a 3½ miles long water tunnel was dug from 40 shafts with 30,000 workers working for 11 years. The tunnel had a total fall of 28 feet. This tunnel fell in decay until major restoration was done by Emperor Hadrian. It ceased to function completely in the 5th Century A. D. and the lake filled up again. In 1854-1870, this lake was drained again by a banker when certain sections of the tunnel were made use of. This tunnel had all the nasty problems of tunnel construction including those created by earth pressure which, as the Romans mention, "put them to the excavation of far greater quantities than estimated".

The Romans successfully solved the problem of river piers on the many bridges forming part of their highways. They used both the techniques of piles and caissons and some of the bridges erected not only carry the heavy traffic of the cities of to-day but also stood the tanks of both the Germans and Allied forces of the Second World War.

The Roman Empire needed harbours for their navy. The huge resources of slave labour and materials available to the Romans made them less sensitive to the proper selection of harbour sites. They built gigantic engineering works, the relics of which are admired today. Most of these harbour have, however, either silted up or succumbed to the sea but their construction proved the possibility of artificial harbours 2000 years ago. Emperor Trajan constructed the two harbours of Centumecellae and Ostia. The former now forms the inner basin of the modern port of Civitavechian which came into existence as a remodeling of Centumeclle after 1850. The harbour worked in its original form for hundreds of years. The other port Ostia is in existence today but silted up and is 2 miles inside the coast. It is interesting to note that the Roman used many techniques of modern harbour construction such as dumping of stones from barges having openings at the bottom and placing concrete underwater.

Whereas so gigantic hydraulic structures furnish evidence of the great practical skill of the Romans, their theoretical contribution is small. The names of the architects and engineers of Romans aqueducts are not known to throw any light on the theoretical accomplishments of their creators. The works are known after the rulers who initiated or completed them. However, during the entire period of Greeks and Romans, from 400 B. C. to 100 A. D. three names are outstanding.

Archimedes (287-212 B. C.) was born at Syracuse in Sicily. After receiving education in Alexandria where he mastered Euclidean geometry and astronomy, he became a friend of Sicilian King Niero II. He is credited with the invention of many machines which impressed the popular imagination and is said to have invented engines of war which terrified the Romans and necessitated a three years long siege of Syracuse. He discovered the first law of hydrostatics that a body immersed in water weighs less by the amount of water displaced by it. He was also a naval architect and invented what is called the "Archimedes Screw", a helical tube round a rotating cylinder used to lift water. This device is still used in Egypt for lifting water for irrigation. He was killed by a Roman soldier whom he asked not to disturb his circles while he was working on his sand model. This was contrary to the orders of the Roman general who gave him a decent burial and befriended his survivors.

Amongst the Roman engineers the names of Vitruvius and Frontinus are worthy of mention. Virruvius was possibly active in the reign of Julius Ceasar. His book "The Architecture" which is in 10 volumes and was written after 27 B. C. remained a standard work for many centuries. Later architects such as Michaelangelo and Baramante were ardent students of Vitruvius. He is credited with the introduction of standard bores for pipes. He described many varieties of conduits and some instruments with which gradients could be set. For Roman aqueducts he adopted a gradient of 1 in 200. Frontinus has very little to say about the technical aspects but made some very frank remarks about the upkeep of the aqueducts. After his return from the Governorship of Britain he was appointed Chairman of the Water Board for Rome and compiled his book "The Aqueducts of Rome" at the age of 97. He mentions all the malpractices and corruption ripe in the management of supplies and specially the illicit tapping of the system by influential citizens and the powerlessness of the staff against them. He even mentions how the inlet pipes to the distribution tanks were enlarged and the standard outlets pipes reduced to create a hidden surplus for illicit sale. Even today we share the feelings of Frontinus that "workmanship of the older works is better than the newer ones".

This magnificent era of hydraulic engineering continued with reduced grandeur in what is commonly called the Middle Ages. There are only few examples of these monumental works of hydraulic engineering such as the aqueduct to the Cathederal city of Sopoleto constructed in the 13th Century. This aqueduct is 700 feet long and 270 feet high, built of graceful and well proportioned pointed arches of 66 feet span. The aqueduct of Constantinople built by, Emperor Justinian, is 720 feet long and 108 feet high. The middle ages may be called the age of religious devotion. It appears in Egypt as well as in Rome that the Government architects, since early times, belonged to the priesthood or were very intimately connected with it. The Latin word Potifex used to this day to denote a priest means "bridge builder". During this period, the energies of the architects and engineers were devoted to construction of churches and a high degree of skill was achieved in construction of dams. The hydraulic works remained limited to the many beautiful bridges including those of the city of Venice. However, in the period (300 A. D. – 1500 A. D.) substantial works of hydraulic engineering were done in the Saracenic Empire that had emerged in the East and occupied the southern coast of the Mediterrenian. The writer has little material available of the Arabs contribution to the science of hydraulic engineering. Empress Zubeida, the wife of the famous Abbaside Caliph, Haroon-ur-Rashid, paid a visit to the Holy cities of Mecca and Medina in 802 A. D. and was greatly moved by the scarcity of water. She ordered the construction of a canal at her own expense. This canal (named after her) was built at a cost of a million and a half dinars and is a great blessing to the cities to this day. The Saracen rulers laid an excellent system of canals and drains between the Euphrates and the Tigris. Caliph Mehdi who acceded to the throne of Baghdad in 775 A. D. built a canal in the central region bringing vast areas under cultivation. Isa canal built by an uncle of Caliph Mansur extended from a place called Anbar on the Euphrates to Baghdad and on to join the Tigris. It was navigable by big ships. A canal taken from the Tigris irrigated the districts north of Baghdad. In the same period, an excellent system of irrigation came into existence in Afghanistan on the banks of the Oxus river. These brilliant works fell to the ferrocity of the Mongols under Chengez Khan (1162 – 1227).

Hydraulic Engineering During the Renaissance (14th to 18th Centuries)

During the Age of Renaissance the intellectual quests of man were sharpended and became the necessary prelude to the impressive ventures of the modern times. The construction of Canal du Languidoc for navigation purposes is an outstanding achievement of the 17th century. Locks (invention of locks is attributed to Leonardo da Vinci but most probably Leonardo perfected rather than invented them) were introduced on a major scale and became an indispensable part of navigation engineering. Started in 1667 A. D. the Canal du Languidoc connects the Mediterranean part of Sete with the Atlantic ocean near Tolouse. From the Mediterrenean the canal rises to a height of 620 feet through 74 locks and descends to Garronne by 26 locks. It is still functioning till this day in its original shape and can take bargess upto 200 tons. The canal excited the admirations of Voltaire and initiated the science of dams which was necessary for its realization and functioning. The discoveries of sea routes from Europe to India and America created the necessity for harbours and docks including dry docks. During the 15th , 16th and 17th centuries many harbours came into existence. A canal system for navigation and irrigation spread over most of France. From the 16th to the 19th century, hydraulic engineering made great strides not only in its application to practical needs but also in the theoretical understanding of the subject. During the late 17th and early 18th century hydraulic engineering made greater use of mathematics and emerged as a distinct science. The eminent engineers of the 18th century, employing mathematics, thus not only laid the foundations of modern hydraulic engineering but also provided the necessary basis for its bifurcation into theoretical and practical fields. However, during the pioneering stages of this development, the theoretical and practical aspects continued to be studied together.

The works of Tulla (Swiss, 1770-1828), specially his plans for Regulation of Rhine through canalisation between Basle and Mayence, though completed after his death, reclaimed large tracts of lagoons and swamps. This great work excited the admiration of Gothe (a great German poet) whose hero in Faust II turns into an engineer seeing the fulfillment of his life's ambition in winning back arrable land from swamps and lagoons. Woltman (1757-1837) and Eytelwein (1764-1848) did valuable work on problems of river training in the German low-lands. Both wrote valuable books on hydraulic engineering. Woltman's work was covered in four volumes. Belidor (1697-1761, French) not only used theories of statics and strength of materials but also hydrodynamics for the design of hydraulic structures. He published four volumes containing description of many works.

To a somewhat more distinct class of pioneers could be ascribed the names of Chezy du Buat, Bazin and Darcy. These engineers did valuable pioneering work in correlating experimental work with theoretical considerations. Chezy du Buat (1718-1798), a French laid the foundations of uniform flow by the publication of formulae known after him. Du Buat (1734-1809) who was Chezy's junior by sixteen years engaged himself to determine the flow characteristics in rivers, pipes etc. and introduced the notion of "hydraulic radius". Darcy established the law of flow in pipes and grannular media and his assistant, Bazin (1829-1917) carried out experiments on open channel hydraulics which to this day are unrivalled in scope and magnitude. We thus see, that by the beginning of the 19th Century, hydraulic engineering had been well established. It is a law of nature that as a science develops, it asks more and more questions. In furnishing answers to these questions, science divides itself into many branches each acquiring the status of a separate 'subject'. For our present study, we will give only a very brief resume of the theoretical developments of hydraulic engineering.

Theoretical Advancements

Galileo (1564-1642) an Italian was the first to challenge the Aristotelan concept of machanics and may be rightly called the father of mechanics, of which hydraulic engineering is a branch. In the field of hydraulics, he can be credited with the origin of the concept of "discharge", parameter of flow which may be measured. His brilliant pupil Torecelli dicovered the formulae $v=2\sqrt{gh}$, for flow through an orifice and conducted field experiments to find the velocity profile in a canal. He applied this formula to a canal and came to the wrong conclusion that the velocity in the deeper layers of a canal should be greater than in the upper layers. It took centuries to rectify this mistake. Certain remarks by Galileo about the resistence to flow in curved channels also led to great difficulties.

The observations of Galileo and Torecelli were experimentally denounced by Mariotte and Pitot in 1700 and later by Darcy and Bazin, all belonging to the French School. The year 1642 saw the death of Galileo and the birth of Newton (1642-1727). Newton put the whole science of mechanics on a rational mathematical foundation. Newton and Leibnitz independently founded differential calculus and Newton is credited with the invention of integeral calculus. Newton's work on the phenomena of viscosity proved of immense value to later investigators. His mathematical ennunciation of the principle of momentum, a fundamental law of mechanics, made many intractable problems soluable. A further impetus of tremendous importance was given to hydraulic engineering by the work of Daniel Bernoulli (1700-1782) by his enunciation of the basic energy equation in 1738. It will be interesting to know that Daniel Bernoulli came of a family of mathematical genii. For three generations the Bernoullis occupied the most eminent chairs of European Universities ranging from St. Petersberg (Leningrad) in the north to Padua in the south. Daniel Bernoulli received his doctorate in medicine for his researches on the action of lungs and was 10 times awarded the French Academy Prize. There is hardly a problem of hydraulic engineering which cannot be solved by the two equations of Newton and Bernouilli (plus the equation of continuity enunciated by Laplace) if the necessary conditions for their applicability could be determined. This of course does not mean that the end of all in hydraulic engineering was reached with these discoveries. These equations in the hands of the physicist of the 18th and 19th century proved to be the basic tools on which the exquisite mathematical edifice of hydrodynamics was built. The mathematical researches of Gauss, Cauchy, Shwarz, Stokes, Langrange, Poisson and Navier furnished the means with which to answer some of the complicated problems of theoretical hydraulics.

In their search for mathematical solutions to hydraulic problems, the scientists of the nineteenth century had to base their theories on an "ideal fluid" which had no friction and could consequently move without loss of energy. Disturbing contradictions arose between the experimental school which had established reasonably accurate formulae of fluid without knowing their complete rationale and the mathematical conclusions which though rational did not fully explain the practical phenomenon. Osborne Reynolds (1842-1912) for the first time partly explained the nature of these contradictions and demonstrated that under certain definite conditions the practical pattern of flow did conform to the theoretical concepts. He determined the criteria for such a happening through a dimensionless number now known by his name. This discovery, though important, was insufficient as it could not furnish the logic for many reliable formulae of the experimental school. For example, no answer could be found as to why the flow should separate from the rear of a cylinder or a bridge pier and form a wake behind it. In a celebrated paper presented to mathematical congress at Heidelberg in 1905, Ludwing Prandtl (Göettingen, died 1959) presented the concept of Boundary Layer Theory. This theory recognised the existence of a thin layer of fluid sticking to the boundaries of the body touching the fluid. In this layer the viscosity of fluid played a dominant role. The layer though thin could explain many of the inexplicable observations. Von Karman (a Hungarian settled in America, died 1962) further extended this theory and introduced the concept of turbulence and framed equations for its magnitude on the basis of 'momentum transfer' for motions of actual fluids. The works of these two great mathematicians, like beacons in a vast unexplored field, furnished the rationale for the formulae of the experimental school. These theories, though of great significance to hydraulics, found their real importance in aerodynamics which has presently achieved an extremely high degree of mathematical sophistication. For many problems of hydraulics a student has to refer to aerodynamics.

In the beginning of the 20th Century, great works of canal engineering were conceived. Czarist Russia planned a vast enterprise of hydraulic works. In solving the complicated problems of these vast works Bakhmetteff perfected the theory of varied flow, (flow of a constant quantity with varying depths), through the use of the simple concept of 'specific energy', which he introduced. Bakhmetteff was the Russian Ambassador at the time of the Russian Revolution and finally settled in America. Besides his other numerous contributions to fluid mechanics he established the National Hydraulic Laboratory in Washington.

In the end of nineteenth century, the era of hydroelectric engineering had set in. As hydraulic machines acquired popularity and pressure pipes and tunnels were being designed in great numbers, Allievi pronounced the theory of pressure impulses, which plays an important role in the design of such works. It was further perfected by Schneinder and Bergeron, two French designers of water pumps.

Hydraulic Engineering in the Modern Age

This review does not include hydraulic machines which, though in general belonging to hydraulic engineering, could be better accommodated in a study concerned with the evolution of machines. These paragraphs have been written from a civil engineer's point of view. The word 'Civil Engineer" is of combined French and Latin origin. The word 'engineer' has its roots in 'Ingenia', a Latin word standing for 'ingenuity' which the Roman legions displayed in their machines of war. In France, a number of army engineers were employed to execute works for the civil population. That body of engineers came to be known as 'Genie Civil'. The achievements of modern civil engineering are most superbly demonstrated in its water works. These may be broadly divided into works done for navigation and structures erected to natural rivers for irrigation and hydro-electric power.

Navigation Works

Suez Canal : Of the many great achievements in this field, four are the most outstanding. The earliest of these four examples is the Suez Canal. During the 17th and 18th Century, the debate about piercing the isthmus of Suez Canal was coloured by the then prevailing misconception that there was an important difference of level between the Mediterranean and the Red Sea. The industrial revolution intensified competition between the European countries lying on the western sea board for the Indian trade. France looked both to the Atlantic and the Mediterranean. In their struggle against the British, the Directory sent Napoleon to occupy Egypt in 1798 and sent with him a distinguished French engineer by the name of Charles Le Pere. He reported that the Red Sea was 30 feet higher and recommended the reconstruction of the old canal of the Pharohas. It was left to M. A., Linant de Bellefonds, another noted French Engineer, to prove in 1853 that a canal was feasible as the difference of levels was small and unimportant. Luck favoured France. Abbas, the Victory of Egypt was murdered and in his place succeeded Said who was a close friend of De Lesseps, a French Diplomat of great vision and charm. De Lesseps had read Le Pere's report but enjoyed the friendship of Linant de Bellefonds. De Lesseps succeded in pursuading Said to sign the First Act of Concessions. The British did everything within their means to stop the French venture but De Lesseps was not deterred by the threats, abuses and machinations of Palmerston (Prime Minister of Britain). In 1859 he himself turned the first spadeful of sand at a site where Port Said was to rise. After the death of Said in 1863, the British, in their tireless effort, succeeded in pursuading Said's successor to withdraw all Egyptian labour. Napoleon III helped the Suez Canal Company with its financial problems which had arisen due to political considerations and the company imported construction machinery to off-set the labour problem. The Canal was formally opened on November 17, 1869 amid scenes of great splendour with the Empress of France heading the procession in the imperial yacht. The Italian composer Verdi was commissioned to write special music for the occasion.

The canal is about 100 miles long with a width of 197 feet and a depth of 43 feet. More than 16,000 ships transit through it every year. The oil cargo of the Middle East alone is more than 72,000,000 tons. It was nationalised in 1956 by President Naseer of Egypt when the famous Suez Conflict took place. The Egyptians propose to enlarge it to enable passage of the biggest tankers of modern times. Its construction cost in 1869 was 433 million French Francs.

Panama Canal : The idea of constructing a canal across the isthums originated after the visit of Columbus in 1502. Two routes were mainly favoured. A canal across Nicaragua or Panama which was a part of Columbia till 1903. The Nicaraguan route was favoured by growing American interest in westward expansion. In 1850, the British succeeded in preventing the U.S.A. from entirely owning any isthmian canal that it might construct. The Americans on the other hand put in a railway line which runs parallel to the present canal and finished the job in 1855, thus taking the first major step. With diplomatic deadlock between Britian and American, and rightly dazed by their success of the sea level Suez Canal, the French under De Lesseps convened a large International Congress in 1879 at Paris.

Under the prestigious personality of De Lesseps the Congress adopted the idea of a sea level canal across Panama. This idea of a sea level canal was brilliantly opposed by a noted French engineer, De Lepinary. With a characteristic vision, De Lepinary proposed the creation of two lakes on the two rivers near each of the canal ends by constructing dams across them. These lakes could then be joined by a cut across the divide separating the catchments of the two rivers. The descent to the sea was to be achieved by constructing lakes at the both ends of the canal. Unfortunately for the French, De Lepinay ideas and his timely serious warnings were ignored and the French Panama Canal Company embarked on its ill-fated venture of constructing a sea level canal, after having obtained concession from the Columbian Government. In 1889, 10 years after the congress, the company discovered the fallacy of the sea level proposal, went bankrupt, and created one of the greatest financial scandals of Europe. The company, before final liquidation, changed its plans to a high level lock type of canal. The company did 78 million cu. yds of excavation of which 30 million was later found useful. In the meanwhile, the Americans forcefully restored the Monroe Doctrine, completely ignored the British, and started independent investigations of the Canal.

The commission appointed by the U.S.A. recommended the construction of a canal across Nicaragua because the French Panama Canal Company was asking a price for their assets which made the alternative of a canal across Panama more expensive. The French Company was desperately hoping for an American take over and, seeing that the U.S.A. preferred Nicaragua, hastened to accept the price offered by the Americans and packed off. This great debate on the choice of the route for the canal lasted in American Congress for more than 6 years and is called the "debate of routes". The Columbian Senate refused to ratify a treaty signed between the Government of U.S.A. and Columbia giving in perpetuity the land required for the construction of a canal. The Americans organized and actively backed by force, a revolt by the Panamians against Columbia, with Panama finally separating from Columbia, forming an independent Sovereign State and granting all concessions to the Americans. Having seen a succession of heads, the Panama Canal Company had still not been able to decide the 50 year old question whether the canal was to be a sea level or lakes and lock type of canal. The matter was referred to an International Board of Consultants. The Board split. A majority of eight decided in favour of a sea level canal and a minority of five recommended a lock canal embodying all the basic features as recommended by De Lepinay, 25 years earlier. As the Chief Engineer of the Project, Mr. Stevans forcefully pleaded the views of the minority, the American President Theodere Roosevelt accepted his recommendations, and the canal was completed in 1914. Later researches convincingly proved that the President's confidence was correctly placed.

The Panama Canal from shore line to shore line is 40 miles long and from deep water to deep water is 51 miles. A ship sailing from the Atlantic to the Pacific passes through a 74 miles long and 500 feet broad channel dredged in the sea before it arrives at Gatun locks. There it is raised to a height of 85 feet through a set of three locks and enters Gatun lake. This artificial lake was created by the construction of Gatun dam on the river Chagre which drained into the Atlantic. After crossing Gatun lake, the ship enters a cut made through the rocky divide separating the Atlatic and Pacific water sheds. This cut is 8 miles long and draws its water from Gatun lake. At the end of the cut, the ship descends 31 feet into another lake, called Miraflores lake, through a single lock. Sailing through the artificial Miraflores lake, the ship descends to pacific sea level through two more locks and enters the channel in the Pacific Ocean.

The canal traffic has grown at an enormous rate since the Second World War with total tonnage crossing the billion mark in 1956. Presently more than 11,000 transits take place in a year.

Saint Lawrence Seaway : Saint Lawrence Seaway is one of the most impressive achievements of modern hydraulic engineering. It virtually converts the 6600 miles of shoreline of Great Lakes into another sea coast. Early works on segments of the pre-seaway system were started in 1700. After the union of Upper and Lower Canada in 1841 all the canals on the Saint Lawrence route were deepened to 9 feet. These were later deepened to 14 feet in 1887. The Welland Ship Canal completed in 1932 was constructed with a depth of 25 feet keeping in mind the future seaway with which it has now been incorporated by an act of legislature. Having failed to obtain American participation in 1932 and 1941, the Government of Canada established the Saint Lawrence Seaway Authority in 1951. Three years after its establishment, the New York State Power Authority was allowed by American Congress to participate in the power generation component of the scheme.

The Seaway begins at Montreal harbour and, going upstream, a ship enters a 16 miles long canal which connects Montreal harbour with Lake St. Louis. The 45 feet differential between these two points is negotiated by two locks. Crossing the Lake St. Louis the vessel arrives at the upstream end of this lake where it bypasses Beauharnois over dam through a system of two locks, each having a lift of 41 feet. This ship enters another 16 miles long power canal which emanates from Lake St. Francis. Between Lake St. Francis and the upstream end of Lake Ontario, the St. Lawrence River itself is the international boundary and has a power dam shared by both countries. This power dam has created a small lake called St. Lawrence Lake. A ship bypasses this dam through two locks of 42 and 45 feet lifts to finally enter Lake Ontario through the thousand Island section of St. Lawrence River where large modifications were carried out. Near the upstream end of Lake Ontario the 27 miles long Welland Ship Canal connects the two lakes of Ontario and Erie having a water level difference of 326 feet. This height is covered through a system of eight locks.

Without taxing the reader with further details about this great venture it will be enough to say that the total cost of Power and Seaway, without the impressive Welland Canal, is over one thousand million dollars. The installed power is slightly less than two million killowatts. The Seaway handles ships upto 9000 tons cargo capacity. The construction of this Seaway required the relocation of many towns, railroads, highways and the heightening of fixed bridges to a minimum of 120 feet. The venture was jointly opened by the President of U.S.A. and the titular head of Canada, the Queen of Great Britain, in June, 1959.

The Navigation Canals in Russia

Russia has probably the greatest canal navigation system in the world. There are more than 200, 000 km of water-ways of which more than 50,000 km are navigable by ships upto a 1000 tons. These exclude the Asiatic system from the Obyenisse mouth to Central Asia and lake Baikal. After the construction of a short but important Volga-Caspian Canal in the Volga delta, Soviet Russia embarked upon the ambitious Don – Volga Canal. This Canal is 62 miles in length and was completed in 1952. With its completion the Russians have joined the Baltic, Black and the Caspian Seas by navigable canals. Unfortunately, detailed information about Don – Volga Canal is not available to the writer but it is said to be one of the great engineering feats of modern times. This canal helps in the transportation of oil from Baku, fish from Astrakhan, corn from the valleys of Kama and Volga, coal from Donetz and merchandise from Persia.

The Era of Dams and Barrages

It is somewhat questionable to attribute the development of water structures including dams and barrages to advances in hydraulics alone. Of no less importance are the corresponding and simultaneous achievements in the various branches of civil engineering such as theory of structures, strength of materials specially steel, hydraulic limes and cement. The common variety of cement is known by the name of Portland cement after the stone quarried near Portland, which resembled in colour and solidity the artificial stones made with cement. This cement became a big commercial commodity in the first ten years of the 20th century. The advances in the theory of structures and a better understanding of the properties of engineering materials made possible the breath taking hydraulic works of the modern era.

Early dams are reported to have existed in southern India and remains of minor dams, probably of the Kushan period can be seen on some hill torrents of the N. W. F. P. Coming to more recent times, the Spanish engineers of the sixteenth century built a 135 ft, high dam at Alicante in 1580 to overcome the chronic shortage of water. It remained in service till the middle of the nineteenth century. Many more dams have been built by the Spaniards since then. In France, reservoirs were needed to feed the ship canals like the Canal du Languidoc. Two earth dams of Saint Fereol and Orviel were built for the Midi Canal. Fereol Dam is 105 feet high. Another dam at Lampay of a buttressed gravity type was built for Languidoc canal. The early calculations for dam have been given by Belidor in his "Architecture Hydraulique". Ignorant of up-lift he recommends a safety factor of 1.5. The great pioneering effort of the French in the design and construction of dams began in the middle of the nineteenth century, initially for water supply purposes. Sazilly and Deleore were the first to emphasise that the stability of a gravity dam was not a mere exercise in the statics (over-turning and sliding) but also a problem of strength of materials, and established the necessity for calculating the internal stresses in the body of the dam. Hundreds of dams had been built all over the western world by the first decade of the 20th century. The dimensions of these structures were to a large extent dictated by the strength of construction materials.

In the evolution of any science, initial failures are inevitable. It was from these failures that the science of dam engineering learnt its great lessons. France which had taken tremendous strides in dam construction also witnessed a number of disastrous failures. The French Government was alarmed by these failures and established a commission under the chairmanship of a noted engineer, Maurice Levy, to enquire into the causes of these failures. This commission discovered that the water which seeped through the foundation of a dam caused an upward thrust commonly known as uplift. This water had the effect of reducing the weight of the dam, which is the basic force responsible for the stability of a concrete gravity dam.

The problems of foundations multiplied with the number and size of the structure, and to solve them, help was sought from other branches of science such as geology. Different types of structures were evolved such as arch, cupola, and buttress types to reduce the volume of concrete where the foundation rock was good. Earth and rockfill dams of substantial heights (upto 550 feet so far), have been successfully built where the foundation rock is either too deep or too weak. Grand Dixen and Movaison dams in Switzerland and Voint in Italy are monumental examples of concrete dams of the modern era. Grand Dixen (nearly a 1000 feet high is the highest in the world) Movaison (an arch dam about 800 feet high) and Voint (an arch 780 feet high) are great examples of the refinements and confidence achieved in investigations, design and construction. The last named successfully withstood a flood wave three hundred feet high over its crest when a mountain slid into its lake. There are several great names associated with these remarkable achievements. Ritter, of Switzerland, in 1913, advocated to treat an arch dams as a fabric of vertical columns fixed at the base and of horizontal arches from abutment. This theory has since been successfully developed by American Engineers. Coyne of France invented another method of analysis. Harza in America and Semenza of Italy have made notable contributions to the techniques of dams.

Earth and rock fill dams like Fort Peck (U. S. A.), Mangla (Pakistan), and High Aswan (Egypt) are examples of dams built on 'sandy' foundations. These dams are in fact huge artificial mountains of earth and rock thrown across the rivers. Such great ventures are to a large extent, due to the tremendous advances in construction machinery and the exhaustion of good sites during the last 50 years.

In the last two decades of the 19th century and the first two of the 20th century a great need arose for irrigation of the vast but parched lands of Egypt and India. Simultaneously in Europe and America, the magic of electricity was creating wonders and the demand for electric power justified a large number of 'run of the river', or 'transference of water from catchment of one river into another type of schemes. The irrigation of lands required the raising of river level by a few feet (say 8 to 15 feet) and this was achieved by constructing a dam of a small height across the river with gates throughout its length. Such a structure is commonly known as a barrage. In the Indo-Pakistan subcontinent, the era of Barrage Irrigation was ushered in by the construction of the Ganges Canal from Hardwar. This canal was opened in 1854 and the personal contribution of Col. Cautley, a British Engineer, played a great role in its successful completion. For quite some time Col. Cautley personally did the surveying and levelling of this canal. Almost the entire excavation was done by the nomadic tribes of Afghanistan. Since then, other great irrigation systems like the Sukkar Barrage and the tremendous irrigation network of the Punjab have been built. The barrages on alluvial rivers of Indo-Pakistan subcontinent are resting on sandy foundations. Since water can percolate freely through such a media, the uplift forces discovered by Maurice Levy have a pronounced influence on the design. Stability considerations require that the structure be heavy enough to counteract uplift forces and resist the pushing action of the impounded water. Economy in the design of these structures was achieved when underground barriers to water percolation known as sheet piles, were introduced. These barriers had the advantage of reducing the quantities of concrete in the barrage and reducing the danger of failure from the washing away of the foundation materials by the seepage water. The efficiency of these barriers was not fully understood till the present century when Warreip Weaver (American 1932) Pavolosky (Russian), and Khosla (Indian) gave mathematical solutions to determine the efficiency and dimensions of such barriers. Trimmu Barrage (Pakistan) was built on these modern theories and since then all barrages on such foundations make use of these discoveries.

Hydraulic Engineering has achieved a remarkable degree of maturity. The need for water is increasing every day. The population explosion of Asia is going to pose a tremendous problem very soon. Already the so far hidden resources underground water are being mined in Pakistan at a scale never dreamt of before. The Chinese are conducting experiments on how to accelerate the melting of the great glaciers to increase water supply. The break-through in the desalinisation of sea water for irrigation purposes is still far away. It is the problem of the present times to devise ways and means of increasing the supply of water on the continental land masses and to carefully utilise and economise on what is already available.

OBITUARIES

May their souls rest in Peace

1. Engr. Daud Beg
   Former President of PEC &
   Former Additional Secretary
   M/O Water & Power GOP
   (Also Conqueror of K-2) in
   Washington

2. Engr. Ahmad Nawaz Cheema
   Vice President, NESPAK
   Lahore

3. Engr. Shafqat Hussain Qureshi
   (Retd.) Director General (H&PP)
   Lahore

4. Engr. Abdul Rashid Khan
   S.E. (Retd.) Irrigation & Power
   Lahore

5. Engr. Ch.Abdul Khaliq
   S.E. Irrigation & Power
   Lahore

GYPSUM-ACID EQUIVALENT FACTOR EVALUATION FOR SULPHURIC ACID USE IN SOIL AND BRACKISH WATER AMELIORATION

By

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ABSTRACT

Gypsum ($CaSO_4$. $2H_2O$) and sulphuric acid (H_2SO_4) both are used as soil amendments to correct sodicity problem of salt-affected soils. The quantity of H_2SO_4 is indirectly assessed from the gypsum requirement of a soil, as the latter can be easily determined in the laboratory. By dividing one gram equivalent weight of H_2SO_4 (49) by that of $CaSO_4$. $2H_2O$ (86), the scientists have established a weight-to-weight (W/W) based equivalent factor ratio of 1 to 0.57 between gypsum and acid. This factor ratio is in use since 1916. Recently, some people have distorted this factor as 1 to 0.01583, which being ir-rational and unscientific is misleading the managers involved in land reclamation. The paper evaluates the conventional and controversial gypsum-acid factors. It is pointed out that the controversial factor 0.01583 obtained after dividing 0.57 by 36 on the ground that the acid available in the market is of 36N concentration, is not convincing. It appears quite confusing to divide a weight-to-weight ratio (W/W) i.e. o.57 by 36N which has a weight-to-volume (W/V) orientation. It is highlighted that the conventional factor 0.57 derived as a W/W ratio between equivalent weights of sulphuric acid and gypsum should not be taken as normality -based, it is the specific gravity of 1.8 plus of 95% V/V concentrated sulphuric acid which itself takes care of a 36N concentrated H_2SO_4 solution that is available in the market. The paper also reviews some basic concepts of chemistry with some mathematical expressions showing that 1N and 36N sulphuric acid solutions are 2.67 and 95% pure by V/V, while the corresponding purity percentage by W/W calculated is 4.79 and 97.89%. The actual weight of pure acid (100% anhydrous) corresponding to a given weight of $CaSO_4$. $2H_2O$ on 0.57 factor basis doesn't change with the change in composition of sulphuric acid solution of 1N or 36N. It is the weight or volume of sulphuric acid solution that will differ with the change in purity percentage or specific gravity of H_2SO_4 available. It is concluded that controversial factor 0.01583 is not fact based and must be rejected in favour of conventional factor ratio of 0.57 which is in close approximation to a 36N acid. For 1N sulphuric acid (solution), the factor ratio between gypsum to acid works out to be one to 11.896 by W/W. The judicious calculation procedure based on 0.57 factor should therefore, be used while calculating amount of 36N concentrated sulphuric acid. Under or over-dozing of acid, otherwise, will not hit the time limited land reclamation targets.

BACKGROUND

No direct chemical method is used to determine sulphuric acid requirement of the sodic or saline-sodic soils. However, gypsum requirement (GR) of a sodic soil can be easily determined in a soil- testing laboratory. The chemists have established a relationship factor between gypsum and sulphuric acid, which is absolutely on gram equivalent weight basis. The equivalent factor ratio for gypsum ($CaSO_4.2H_2O$) to sulphuric acid (H_2SO_4) is 1 to 0.57. It is obtained by dividing one gram equivalent weight of H_2SO_4 (49) by that of gypsum (86). Being a ratio, it can have any unit say gram, kilogram or ton.

Both gypsum and H_2SO_4 are used as soil amendments to correct sodicity problem in salt-affected soils. The acids are mostly used in calcareous sodic or saline sodic soils. These are detrimental to soil when used in excess. The adoption of any wrong calculation procedure may lead to over or under estimation of the chemicals. In both cases the time limited reclamation targets cannot be achieved. Some statements published in the literature (Hussain, 2001) about self made factor are confusing the soil scientists from the last few years.

Such statements ridiculously claim that in contrast to fact-based 0.57 factor, the factor 0.01583 should be used in calculations. According to it about 0.01583 ton of H_2SO_4 in contrast to 0.57 ton would compensate (or equate) one ton of gypsum. Thus in contrast to the fact, acid is claimed to be the cheapest even than gypsum if calculations are made in the light of new controversial factor. This is not true. Acids are about 4 to 5 times expensive then gypsum. The reason advanced for this new factor is that the conventional factor 0.57 is only valid when H_2SO_4 is one normal (1N) i.e. it contains one equivalent of H_2SO_4 but the H_2SO_4 available in the market is of 36 equivalents. Thus, dose determined by 0.57 factor is 36 times more estimated when 36N acid is used. So divide 0.57 by 36 to get the equivalent factor of 0.01583 for 36N acid, available in the market. This is not fact based, rather it is confusing and misleading the young scientists.

DISCUSSION

i. Preliminary concept view

The factor 0.57 is a weight-to-weight (W/W) ratio between gram equivalent weights of 100% pure acid and gypsum, while 36 (actually 36N H_2SO_4 containing 36 *numbers* of equivalents not *gram equivalent weights*) by which it is divided is a normality concept with W/V orientation. It appears really disturbing to divide a W/W by W/V ratio (two different concepts). Actually, factor 0.57 is not a ratio between number of equivalents of both the substances. It is a ratio between the gram equivalent weights of both the substances. There is a substantive difference in the ratios between number of equivalents and those obtained from gram equivalent weights of two different substances. Chemically, one equivalent of a substance will equate one equivalent of another substance. But the same number of equivalents of two different substances would carry different weights.

On the other hand, if the numeral 36 is assumed simply the number of equivalents of market available H_2SO_4, it again begets the confusion. It seems unjustified to divide 0.57 (a ratio obtained after dividing the one equivalent corresponding weight of sulphuric acid i.e. 49 by one equivalent corresponding weight of gypsum i.e.86) simply by number of equivalents. Why it should not be divided then by number of grams corresponds to 36 number of equivalents of H_2SO_4. If it is to be divided by number of 36 equivalents, the original factor 0.57 should have been one. One number of equivalents of H_2SO_4 divided by one number of equivalents of $CaSO_4.2H_2O$ will definitely give a factor ratio of one. In such a factitious case of calculus the factor would have been 1/36 = 0.0277, instead of 0.57/36 = 0.01583. This negates the basic equivalent weight ratio of 0.57. On the other hand (ignoring W/V ratio), if factor ratio 0.57 were divided by weight corresponding to 36 equivalents, the factor would have been 0.57/ 49 x36 = 0.0003, it is again not convincing.

There are still some other points, which remain un-addressed in context of the new controversial factor (i.e. 0.01583). The books on chemistry read that both EQUIVALENT WEIGHT and NORMALITY are two different terms. The equivalent weight always relates to a pure single entity and is expressed in say gram (gram equivalent), while the normality is a unit of concentration of solution (two or more entities) with weight-to-volume orientation. Normality is defined as number of equivalents of a substance dissolved pre litre of the solution, not solvent. Thus it appears quite confusing to divide 0.57, a weight-to-weight (W/W) ratio by 36N, which is actually a weight-to-volume (W/V) ratio. It will also be relevant to state that not even a single book in line points out that such conversions for soil amendments are on normality basis (Ahmad and Chaudhry, 1997; Fireman and Branson, 1965). All the books read that such conversions (Table I) are absolutely based on their equivalent weights.

Another point that comes to mind is that one gram equivalent weight (49 gram) of 100% pure anhydrous sulphuric acid if taken and no any other liquid is used to make up solution volume up to one litre, can we say it 1N solution. On the other hand, if we weigh 49 grams of 100% pure anhydrous sulphuric acid and make volume up to one litre by adding it to water, does it really mean H_2SO_4 solution of 1N. In both cases the acid weighs 49 grams. But in first case it is not 1N solution as is the case in latter instance. Therefore, it is not the equivalent weight only that accounts for normality. For normality, equivalent weight of a substance must have a solution volume by one litre. Supporting the W/V concept of normality, if acid is a solution, even then the figure 36 (36N; W/V ratio) used to divide 0.57 should have considered weight of both the components of solution i.e. solute and solvent, instead of merely taking weight corresponding to 36 numbers of equivalents of sulphuric acid as solute only. This controversial factor (0.01583) needs still certain other technical explanations at the part of the initiator of this controversy.

ii. Mathematical Explanations

It is recommended that conventional factor ratio of 0.57 must not be disturbed while estimating H_2SO_4 corresponding to a given quantity of gypsum. This is on one gram equivalent weight basis for both sulphuric acid and gypsum, not simply on the basis of their number of equivalents. The amount of 36N sulphuric acid calculated with 0.57 factor would not be 36 times higher as compared to that of one normal solution (1N). In latter discussions we will rather see 0.57 factor in close approximation to a 36N concentrated sulphuric acid solution. This can be illustrated with few numerical examples:

Example No.1: You have determined 1000 kg gypsum requirement of a calcareous sodic soil. You have 1N (one equivalent H_2SO_4 solution) sulphuric acid and 36N (36 times more concentrated than 1N H_2SO_4 acid) sulphuric acid. How much sulphuric acid solution of each category of acid will you recommend?

Explanation:

According to conventional factor (1 kg gypsum = 0.57 kg of 100% pure sulphuric acid) about 570 kg of 100% pure anhydrous sulphuric acid would be required. Now you are to have 570 kg of acid on 100% purity basis. But neither 1N nor 36N sulphuric acid often called concentrated sulphuric acid, is anhydrous or 100% pure. Both are the solutions. The 1N H_2SO_4 acid is containing acid @ one equivalent per litre of solution, while 36N is containing 36 number of equivalents dissolved per litre of the solution. If it is 36 N

H_2SO_4, it will be 95% pure (USDA Salinity Staff, 1954) by volume-to-volume (V/V) with a specific gravity near about 1.8 or if it is 1N H_2SO_4, it may be 2.67% pure by V/V as per justified calculation procedures.

Now, if you want 570 kg of pure acid converted into volume units say in litres then specific gravity of the pure acid i.e. 1.8337(say kg/litre) may be used for the conversion. So 570 kg of 100% H_2SO_4 will be equal to 310.84 litres of 100% pure anhydrous acid. If it is 36N sulphuric acid (95% pure by V/V), you will measure a volume of 327.2 litres of it to have 100% pure anhydrous sulphuric acid equivalent to 570 kg. On the other hand, if it is 1N sulphuric acid, you will have to measure 11641.95 litres of it (as it is 2.67% pure by V/V) to have 310.84 litres of pure 100% anhydrous sulphuric acid corresponding to the weight of 570 kg of 100%pure anhydrous sulphuric acid.

So, the quantity (570kg or 310.84 litres) of 100% pure acid determined by 0.57 factor would remain the same. It is the volumetric measurement or weight of the 1N or 36N sulphuric acid solutions corresponding to these volumetric measurements that will actually differ. Analysis of the fact reveals that volume of 36N acid will be about 36 times less than that of 1N sulphuric acid even in calculations with 0.57 factor ratio.

iii. Acid purity in relation to Normality

Now the question may arise about the justification of 95% V/V for 36N sulphuric acid (which is actually a solution). This is fact that 36N sulphuric acid called concentrated sulphuric acid produced by contact process is not 100% pure or anhydrous. It contains water mixing and is only 95% pure by V/V with specific gravity of 1.8 plus. Normality characteristic also indicates that it is an acid solution, not pure acid. A pure anhydrous sulphuric acid should not be confused with 1N or 36N sulphuric acid solutions.

Let us prove that 36N locate its root in 95% V/V purity of sulphuric acid. It indicates that 100 ml acid solution contains 95 ml acid (pure). Proceeding to normality concept, we may say that in one litre solution, the quantity of acid will be 950 ml. The specific gravity of the pure sulphuric acid is about 1.8337 plus say g/ml. So to translate 950 ml volume into grams for making it fit in the formula of normality, we will multiply 950 ml with 1.8337. This will give about 1742 grams of sulphuric acid. To convert it into number of equivalents of sulphuric acid in one-litre volume of solution, we will divide it by one equivalent weight of sulphuric acid i.e. 49. This will give 36 numbers of equivalents in one litre solution. So it is proven that 36N sulphuric acid solution is 95% pure by V/V (USDA Salinity Staff, 1954).

iv. Specific Gravity-based Calculation Concept

Conveniently, calculations are also attempted on the basis of specific gravity. If a concentrated acid (which is actually a solution) has specific gravity of 1.8(kg/litre) then to have the amount of pure acid as 570 kg in the previous example, we will measure316 litres of concentrated sulphuric acid solution at the @ 1.8 kg acid/litre of the acid solution. The pure acid almost has a specific gravity of 1.8337 plus.

The mathematical analysis reveals that specific gravity 1.8 plus is actually linked with 95% sulphuric acid by V/V and it itself takes care of 36N concentrated sulphuric acid solution. It is further clarified with an example.

Example No.2: Suppose you have two types of sulphuric acids, one having specific gravity of 1.8 (36N, 95% pure by V/V or 97.89% by W/W) say kg / litre and other with 0.05 (1N, 2.67% pure by V/V or 4.79% by W/W). The pure i.e. anhydrous sulphuric acid corresponding to 1000 kg gypsum requirement on the basis of 0.57 factor will be 570 kg. In both the cases you have to measure a different number of litres of each type of acid to have 570 kg of pure anhydrous sulphuric acid. We will measure 316 and 11400 litres of sulphuric acid with the corresponding specific gravity of 1.8 and 0.05. It is the volume of the solutions or weight of the acid solutions in both the cases that will differ. The weight of pure sulphuric acid would remain same in both these volumetric measurements. The 36N multiplied by one-gram equivalent weight (49) of H_2SO_4 acid would roughly weigh 1764 grams or 1.764 kg sulphuric acid per litre of sulphuric acid solution of 36N, available in the market as concentrated sulphuric acid. It is almost equal to specific gravity (1.8). So the conventional calculations already take care of 36N in term of specific gravity. Thus, the volume measured to have 570 kg pure sulphuric acid from 36N sulphuric acid solution would be almost 36 times less than that of 1N acid in contrast to the one claimed otherwise. It is the specific gravity considered together with purity percentage of the sulphuric acid that determines the quantity of pure H_2SO_4 in one litre sulphuric acid solution

The slight variation in specific gravity values of 1.8, 1.833 or 1.8337 etc of sulphuric acid should not be confused as it varies with the purity percentage of sulphuric acid. Some say it 95% pure, while the other claim it 96% pure by V/V. The slight variation even in the specific gravity of a pure acid (anhydrous say 100%) may be due to slight difference in temperature at which it is measured. Temperature affects the volume and change in volume at any given mass in the formula of density will affect the density and consequently the specific gravity of the acid. Specific gravity of pure acid is 1.8337 plus at 25°C and the pure acid freezes at 10.5°C. The 100% pure acid is not prepared through contact process. It is 95% pure by V/V and is 36N. Pure acid means 100%anhydrous sulphuric acid with Hammett acidity function (H_0) value of 11.9, which is also a liquid at room temperature and is obtained after vaporizing 95% V/V or 36N sulphuric acid produced by the contact process.

v. Dilution Factor and Risk Analysis

The calculations show that pure sulphuric acid of 11.4 ton equivalent to 20 ton/acre of gypsum on 0.57 factor basis measuring 6333 litres of 36N sulphuric acid @ 1.8 specific gravity (for convenience say kg per litre) will undergo dilution by 64 times when an acre of land receives about four acre inch irrigation measuring 410916 litres of water. Thus even 36N acid undergoes dilution to 0.5N, which is not apparently so dangerous. However it is emphasized that acids should be used judiciously so as to protect soil from deterioration.

However, its application to high RSC water is satisfactory. Sulphuric acid doesn't effect SAR of irrigation water. It is the gypsum that is suitable for both RSC and SAR waters. Thus sulphurous acid generators are not amicable to all types of brackish water. However, gypsum solubility is limited in irrigation water and is affected by many factors (Javaid *et al.*, 1999). A different calculation procedure in case of irrigation waters is adopted (Javaid *et al.*, 2000). It is the gypsum that provides calcium to help increase pHc and avoid precipitation even in case of a negative RSC (Javaid *et al.*, 1997). Our soils have low cation exchange capacity (CEC) because of dominating illite type clay minerals in our soils (Ranjha *et al.* 1993). The average value of CEC in our soils is 8-12 cmol (+)/kg. The optimum concentration of calcium in soil solution at this much CEC is about 10 me/L. The soluble calcium (Ca) released in excess to this level with the use of acids will leach down and fix the phosphorus also. Thus the solubility of gypsum (20-28 me/L) is adequate to furnish 10 me/L soluble calcium, the optimum exchange level for our low CEC soils. Similarly, conversion of mica minerals into vermiculite mineral by protonation with acid-use may cause relatively high fixation of potassium from potassium fertilizers, hence making it less available to the crops (Rahmatullah *et al.* 1995). Loss to useful microbial life is another drawback of acid-use. The writer has enumerated the merits and demerits of acid-use technology in full page articles published in the Nation of February8, 2001., June 21, 2001 and in Dawn of July 6, 2001. The same is referred here for those interested in knowing the details.

vi. W/W Concept of 1N and 36N Acid

We can translate the calculations on weight-to-weight (W/W) basis in context of 1N and 36N sulphuric acid. The following examples will illustrate this concept.

Example No.3: In case of 1N: 49 grams H_2SO_4 are present/1000 ml acid solution

49 grams H_2SO_4= 26.72 ml of H_2SO_4 @ specific gravity of 1.8337 (g/ml)

So 1 N sulphuric acid solution volume (one litre) = 973.28 ml H_2O + 26.72 ml H_2SO_4

If 1 ml of water =1 gram H_2O and 1ml H_2SO_4 =1.8337 gram H_2SO_4, then total weight of one litre of 1N sulphuric acid solution = 973.28 gram H_2O + 49 gram H_2SO_4 = 1022.28 grams.

Thus the purity of acid in1N acid solution by W/W would be 49 x 100/1022.28 = 4.79%.

In case of 36N: 49 x 36 =1764 grams H_2SO_4 is present/ 1000 ml acid solution. 1764 grams H_2SO_4 = 961.98ml of H_2SO_4 @ specific gravity of 1.8337g / ml. So 36N acid solution split up will be = 961.98 ml H_2SO_4 + 38.02 ml H_2O

If 1ml H_2O = 1gram H_2O and 1ml H_2SO_4 = 1.8337gram H_2SO_4, then total weight of one litre of 36N concentrated acid solution =1764 gram H_2SO_4 + 38.02 gram H_2O = 1802.02 grams.

The purity of sulphuric acid in 36N acid solution by W/W would be:

1764 x 100 / 1802.02 = 97.89 %.

So on W/W basis the weighing of 570 kg of 1N diluted (containing one equivalent of acid) and 36N concentrated sulphuric acid solution will actually contain 27.30 and 557.97kg of pure acid, respectively. Thus you have weighed 570 kg of 1N and 36N acid solutions not the 570kg of pure H_2SO_4 corresponding to 1000kg of pure gypsum for which ratio between gypsum to acid is worked out as 1 to 0.57 on gram equivalent weight basis of 100 % pure entities. So to have 570 kg of 100 % pure anhydrous H_2SO_4, you are bound to weigh 11899.79 kg of 1N and 582.29 kg of 36N acid solutions. In case of 1N and 36N acid solutions (weighing

11899.79 kg and 582.29 kg, respectively to have 570 kg of pure acid corresponding to 1000 kg gypsum on the basis of 0.57 factor ratio), the corresponding weight of water would be 11329.79 kg and 12.29 kg. So excessive weight measured in each case of 1N or 36N will share from water (whatever weight it contributes) doesn't affect soil on its application.

It is clear from the above calculation work that the 36N H_2SO_4 and 1N H_2SO_4 are acid solutions (concentrated or diluted) which are about 95% and 2.67% pure by V/V and 97.89% and 4.79% pure by W/W. Therefore, one normal (1N) or 36N concentrated sulphuric acid solutions should not be mistaken for 100% pure anhydrous sulphuric acid. The word sulphuric acid should not be confused with sulphuric acid solution of 1N or 36N. The calculations worked out on acid purity basis in 0.57 factor regardless of 1N or 36N will have the same weight of pure acid. It will be the weight or volumetric measurements of the acid solution that will actually differ, depending upon the degree of impurity. The calculations in the subsequent notes will reveal that the factor 0.57 is actually meant for 36N sulphuric acid. Exploration of technical literature regarding conversion factor (table-1) also reveals that some institutions have written 36N with H_2SO_4, while referring 0.57 factor (IWASRI.,1992).

vii. W/W Concentration based Factor Analysis

The factor ratio of 1 to 0.57 between gypsum and sulphuric acid is absolutely on the basis of their gram equivalent weights, not on 1N or 36N basis which actually denote an impure sulphuric acid containing water in it. A 36N concentrated sulphuric acid solution according to the previously worked out calculations is 97.89% pure by W/W, while 1N sulphuric acid solution is 4.79% pure by W/W (however, percentage by V/V will vary). Assuming gypsum as 100% pure and acid as 4.79% (1N) and 97.89% (36N) by W/W different factor ratios between gypsum to sulphuric acid would be different.

For 1N solution which has 4.79% pure sulphuric acid, the weight of 1N acid solution to adjust 49 gram i.e. equivalent weight of pure acid would need 1022.96 grams of 1N acid solution. To have a ratio equivalence, this weight of 1N i.e. 1022.96 gram will be divided by 86 (equivalent weight of gypsum) and the factor ratio will be =11.896 instead of 0.57, which is for pure acid. Similarly, for 36N acid (97.89% pure by W/W) this factor would be 50.056 / 86 = 0.582. So we may have the following factor ratios for different categories of the sulphuric acid against a unit weight of pure gypsum.

a. If it is 100% pure anhydrous sulphuric acid, then the gypsum to sulphuric acid ratio =1: 0.57

b. If it is 1N sulphuric acid (solution) = 1: 11.896

c. If it is 36N sulphuric acid (solution) = 1:0.582

So, in case of 100% pure acid, 1N and 36N sulphuric acid solution, we will weigh about 570, 11896 and 582 kg (respectively) of all three categories of the sulphuric acids corresponding to 1000 kg of gypsum requirement. It reflects that amount of 36N concentrated acid is almost 20 times less by W/W than that of 1N acid solution for having 570 kg of pure acid (not solution). This 20 times less W/W ratio should not be confused with 36 times on the basis of equivalents. It is on weight basis. The 20 times less ratio multiplied by specific gravity of 1.8 would adjust 36 times increase in the ratio.

viii. Economic Analysis

The price of sulphuric acid is about Rs.6000/-per ton, while one ton gypsum costs about Rs.800/-. The price of one ton gypsum produced within calcareous soil (on one ton gypsum equivalent to 0.57 ton sulphuric acid basis) would be Rs. 3420/-, which is about four times higher than gypsum available as mineral in the market. So acid-use is not cost effective. It is the gypsum and gypsum only that is the farmers' best friend. Gypsum used in combination with physical methods of land reclamation also reduces the cost of reclamation (Ahmad *et al.*, 1995). Over thirty benefits from its use on land have been documented (Wallace, 1994).

CONCLUDING REMARKS

1. The factor that one ton gypsum is equivalent to 0.01583 ton sulphuric acid for 36N concentrated sulphuric acid is not fact based and is misleading the land reclamation managers. The true factor of gypsum to acid is one to 0.57.
2. The conventional factor 0.57 derived as a ratio between gram equivalent weights of pure H_2SO_4 and gypsum should not by mistaken as normality- based, it is the specific gravity of 1.8 plus of 95% (V/V) acid that itself takes care of a 36N concentrated sulphuric acid solution (that is available in the market) in 0.57 factor.
3. The calculations show that 36N concentrated sulphuric acid is 95% pure by V/V and 1N is 2.67% pure. The calculations by weight also indicate that 36N acid solution contains 97.89% pure H_2SO_4 by W/W, while 1N sulphuric acid is 4.79% pure.
4. Regardless of 1N or 36N the calculations made on the basis of specific gravity, V/V or W/W percent purity would give a different weight or volume of the slphuric acid solution (1N or 36N) for any given amount of pure sulphuric acid (100% anhydrous) determined by 0.57 factor. The amount of pure acid will remain the same in both the solutions, it will be the weight or volume of the 1N or 36N sulphuric acid solutions that will differ, depending upon the degree of impurity.
5. The word sulphuric acid should not be confused with 1N or 36N sulphuric acid solution. The factor ratio of gypsum to acid of one to 0.57 is on the basis of their 100% purity, it has nothing to do with 1N or 36N because it is absolutely on equivalent weight basis with their 100% pure substance.
6. Gypsum to sulphuric acid factor ratios of 1: 11.89, 1:0.582 and 1: 1.57 may be used for 1N, 36N or 100% pure sulphuric acid, respectively.
7. Generally the factor 0.57 is meant for 36N sulphuric acid available in the market.

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Table 1:Soil and water amendments and their relative ability in supplying calcium

Amendment	Chemical composition	Physical description	Solubility in cold water (kg/m^3)	Amount equivalent to 1 kg of 100% gypsum (kg) †
Gypsum*	$CaSO_4.2H_2O$	White mineral	2.4	1.0
Sulfur**	S	Yellow element	0	0.2
Sulfuric acid*(36N)	H_2SO_4	Corrosive liquid	Very high	0.57
Hydrochloric acid(12N)	HCl	Corrosive liquid	High	1.71
Lime sulfur*	CaS_2 9% Ca + 24% S	Yellow-brown solution	Very high	0.8
Calcium carbonate**	$CaCO_3$	White mineral	0.014	0.6
Calcium chloride*	$CaCl_2 . 2H_2O$	White salt	977	0.9
Ferrous sulfate**	$FeSO_4.7H_2O$	Blue-green salt	156	1.6
Pyrite**	FeS_2	Yellow-black mineral	0.005	0.5
Ferric sulfate**	$Fe_2(SO_4)_3.9H_2O$	Yellow-brown salt	4400	1.09
Aluminum sulfate**	$Al_2(SO_4)_3.18H_2O$	Corrosive granular	869	1.3
Calcium nitrate*	$Ca(NO_3)_2.2H_2O$	-	-	1.06

**Suitable for use as a water or soil amendment*

***Suitable only for soil application.*

†As a generai rule, it is suggested that the rates of gypsum and sulfur calculated be multiplied by the factor of 1.25 to compensate for the lack of quantitative (assumed to only 80%) replacement.

RATIONAL USE OF CEMENT FOR MAKING CONCRETE MIX

By

Engr. M. Gulzar A. Qazi

Concrete mix is made by mixing certain quantities of cement, fine aggregates, coarse aggregates and water in such proportions that the mix so formed gets the required workability and attains the prescribed strength after setting. Admixtures are also added when needed. It is a highly technical job to design a concrete mix i.e. to work out the proper gradation of the aggregates and also exact proportions of all ingredients for getting workability and strength prescribed for the concrete mix to be made. Great care is taken while designing the concrete mix to make rational use of cement by keeping the cement consumption as low as actually required. Proper quality management is also required to maintain the workability and strength while making each batch of the concrete mix. Since such technical facilities cannot be afforded at site of each work, concrete mix is never made at site of works in the developed countries but is supplied readily from the Batching Plants suitably located for proper distribution. There being a very heavy competition for sale of concrete mixes, at each Batching Plant, the most competitive designs with all the related ingredients for making the concrete mixes of various specifications are kept ready so that on receiving any order even through a telephonic call, the concrete mix of the required specifications is promptly supplied to each customer at the site of his work at the time of its pouring. Thus the Batching Plants provide a very useful service to the people with prompt and reliable supply of concrete mixes.

In the developing countries and with special reference to Pakistan, the conditions are almost reversed. The concept of sale of concrete mix does not exist. Therefore the concrete mix is made at site of each work by adopting conventional mix ratio of the ingredients. The two conventional concrete mix ratios of cement : fine aggregates : coarse aggregates normally used are : (a) 1 : 2 : 4, for cube strength 3000 psi, and (b) 1 : 1.5 : 3 for concrete of higher strength, say 4500 psi. The cement contents prescribed per 100 cft of the concrete mixes are about 17.5 bags and 22.5 bags respectively. Provision is generally made in most of the works to use the above mentioned proportions of concrete mix. Some other proportions are also used which too are based on the above concept i.e. by prescribing the proportions of the ingredients, strength of concrete and number of bags of cement to be used per 100 cft of concrete. If the concrete mix is properly designed for the above mentioned strengths, the proportions of the ingredients would differ and the other glaring difference would be that the cement requirement for each or those would be quite less than that prescribed above. This is because some extra allowance of cement is provided in the conventional system to cover the human errors and other omissions inherited in the system. Those errors and omissions cannot be avoided completely in the conventional system because the experts for designing the concrete mix and the adequate quality management during the process of making the concrete mix cannot be afforded at site of each work. Besides, there is every possibility that the strength of concrete produced with the conventional system might not be as reliable as in case of the Batching Plants where the quality is assured through an adequate quality management. From the above it transpires that in addition to some disadvantages, there is certain wastage of cement inherent in the conventional system. Perhaps, such wastage is not in notice of general public but still it is a national loss and also increases project costs accordingly. Despite these shortcomings, it is amazing that necessary remedial measures do not seem to have been taken. The introduction of the system for sale of properly designed concrete mixes with rational use of cement could perhaps be a suitable remedy in this connection. The apparent major reason for not adopting the remedy might be that since the public is generally unaware of the wastage of cement inherent in the conventional system, the economic feasibility for the new system might not have been possible. In order to take a start, it might be advisable to try the system for rational use of cement in a limited area. That would facilitate an economical and technical comparison between the current and new systems. If the results are glaring in favor of the new system, its scope be gradually extended. In this connection the following suggestions be considered.

(1) The commercial organizations interested with manufacture of large quantities of concrete products preferably at concentrated locations, should be in a position to start the research work for proper design of their concrete as well as provide proper quality management. An example for such organizations could be the factory for making precast concrete roof members. There are several such factories in Pakistan and some of those have quite a flourishing business for manufacture of various type of the precast concrete roof members. Those factories generally use two type of concrete mixes for making : (a) reinforced concrete and (b) prestressed concrete. The prescribed cube strength of each type is 3,500 psi and 6,250 psi respectively. Based on the conventional system, it is understood that the cement used for the two reinforced concrete mixes might be about 17.5 bags and 27 bags respectively. But if an attempt is made to get the concrete mixes designed properly and also the current quality management slightly improved, the use of cement contents could be reduced by an appreciable margin. Thus the input cost of the factory made products would be saved accordingly. The expenses for research work for the rational use of cement and maintaining quality management would be quite nominal as compared with the above savings.

When management of some of the factories get sufficient experience for designing the concrete mixes for various strengths, they might like to get further benefit by utilizing their factory made concrete mixes in other works located in near vicinity of the factory. After successful attempts they might eventually decide to sell the concrete mixes in the open market and also install Batching Plants for that purpose. When an example is set, the other organizations and investors might also be induced to pick up this trade and thus the system could go on expanding.

(2) The Government should provide suitable incentives to the investors by allowing some tax rebates in import of the Batching Plants for initial use but later on those could be replicated in the country. Sale of the concrete mix should also be allowed on basis of the prescribed strength, workability and other required features, if any, without laying any condition to follow the prescribed proportions of the aggregates and the cement contents to be used. If so, the Batching Plants management should be held fully responsible to supply the concrete mix strictly according to the requirements of the purchasers.

Since the price of cement has gone very high and also Government is contemplating an ambitious plan for various development works in the country, there is an immediate need to start the research work for rational use of cement for making concrete mixes. In this connection the above suggestions provide food for thought for the concerned organizations especially in the private sector to try the new system. This would provide them the opportunity to serve the national cause for economizing the cement consumption and also make great improvements in their business by adopting the proper technology.

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STUDY OF AIR AND LIQUID COOLING FOR MICROELECTRONICS DEVICES

By

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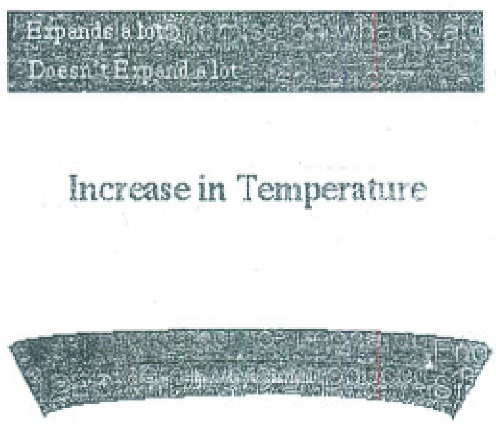
Why We Need To Cool Microelectronics Devices

In today's microelectronics, total system dissipated power levels are increasing with every new design. The dimensions on the chip are decreasing day by day and the devices are generating more heat. It has become important to operate these devices at lower temperature because of following factors.

1. Thermally Induced Failure

We know that, in general, materials expand when it is heated up. With the increase in temperature some materials expand more than others. If two different materials are glued together which normally happens in the microelectronics the materials will pull and bend against each other . [2]



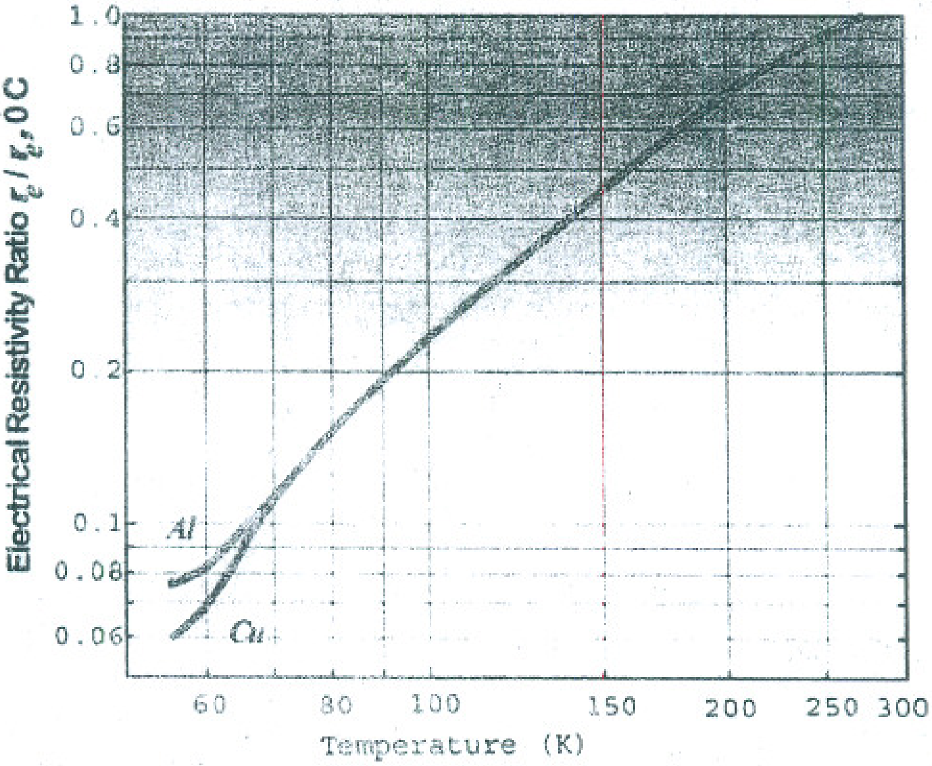
The parts of a computer chip are very small and due to small movements due to temperature changes can wear out and break. This problem is known as thermally induced failure and can be eliminated using the devices at lower temperatures.

2. Electronic Resistance

The electronic components in the microelectronics are interconnected to each other through the metallic wires. As the temperature increases the resistance of the metal also increases and hence the movement of electrons decreases.

The following figure shows that how the electrical resistance of Copper and Aluminum increases with the increase in temperature.

Electrical resistivity ratio for aluminum and copper at low temperatures. [5]



Introduction

Air Cooling

Both forced and natural convection air cooling are being used for the cooling of microelectronics devices. Natural convection air flow is insufficient for cooling until, a heat sink is employed which will improve the thermal heat transfer reducing the temperature of the heated microelectronic device. If the natural air flow is not sufficient for the cooling of the heating surface, a fan is used as a source of forced convection. Any of the air moving devices used for the purpose of cooling do not need any external arrangement of equipment. In the modern era as the size of microelectronics are decreasing day by day new innovative construction have increased the surface area of the heat sink without substantially increasing the volume of heat sink. [1, 3, 4]

Liquid Cooling

Liquid cooling is the latest mode to cool the heated microelectronics. It overcome all drawbacks of air cooling and can remove heat with considerably less flow rate.

Liquid cooling can be employed in two ways.

(1) Indirect liquid cooling.

(2) Direct liquid cooling.

1. Indirect Liquid Cooling

Indirect liquid cooling is a method in which the liquid does not come in contact with the microelectronic chip. In direct liquid cooling a good thermal conduction path is provided to a liquid cooled cold-plate attached to the module surface as shown in the figure 1. The advantage of indirect liquid cooling over the direct liquid cooling is that, we do not need to worry about the selection of coolant. Any type of liquid can be used because it will not come in contact with the microelectronic chip. Water is the most widely used liquid for the indirect liquid cooling because it is the cheapest liquid available on earth. [1, 5, 6]

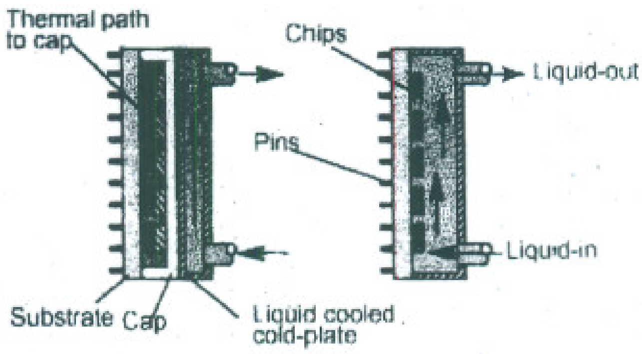


Figure 1: Indirect and direct liquid immersion cooling for microelectronics.[5]

2. Direct Liquid Cooling

Direct liquid immersion for the cooling of microelectronic devices was first introduced in 1960s. In direct liquid cooling there is no physical wall separating liquid and the chip. In direct liquid cooling the heat is removed directly from the chip without any thermal resistance and hence it is more efficient than the indirect liquid cooling. This method provides a high value of heat transfer co-efficient.

There are several coolants which can provide adequate cooling, but only a few a chemically compatible. Water is one liquid which has very desirable heat transfer characteristics, but it is generally unsuitable for the direct immersion cooling because of its chemical properties. The most commonly used liquids for direct immersion are Fluorocarbon liquids (Fc-72, Fc-80 etc.) in spite of their poorer thermodynamic properties but excellent compatibly with the microelectronics chips [1]. At, same time these liquids are far more expensive than water.

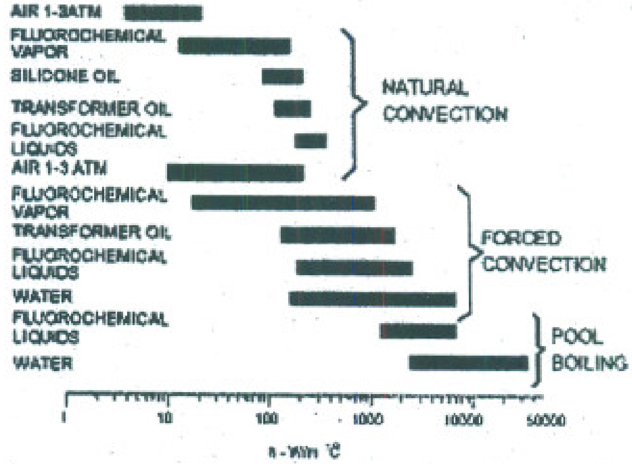


Figure2: Magnitude of heat transfer coefficients for various coolants and modes of convection.[5]

Modes of Heat Transfer in Microelectronics Devices

The common modes of heat transfer in micro-electronic devices are. [7]

1. Conduction.
2. Convection.
   (a) Natural (b) Forced
3. Radiation.
4. Boiling.

Properties of Air and Water [5]

Medium	Specific Heat	Mass Density
Water	4217 J/keg	998 kg/m^3
Air	1060 J/kg^oC	1.2 kg/m^3

Flow Volume Comparison

The flow volume needed for water and air cooling is calculated according to the following formula.

Temperature rise of fluid = Power (watts) / Sp. Heat (J/Kg.sec) x Mass density (Kg/m^3) x Flow vol. (m^3/sec) [1]

Assumptions

1. Steady-State operation.
2. Power dissipation = 500 watts
3. Temperature Rise = 15^o C
4. Atmospheric Pressure

Air:

Flow volume = 500 watts / 1060 J/ kg^o Cx 1.2 (Kg/m^3) x 15^o C

Flow volume = 0.0393 m^3/sec

Water:

Flow volume = 500 watts / 4217 J/ kg^o C x 998 (Kg/m^3) x 15^o C

Flow volume = 7.92×10^{-6} m^3/sec

Looking the above result it is evident that there is a significant reduction in the flow volume required for the water cooling as compared to the air cooling at same temperature and powder dissipation.

Heat Transfer Co-efficient Comparison

The value of heat transfer co-efficient is a real reflection of the heat that can be removed in a system. Higher the value of heat transfer co-efficient more will be the amount of heat which can be removed from the micro-electronic device.

Assumptions

8. Steady- state operation
8. Forced convection cooling
8. Flat Plate

For Water:

$Nu = 0.664\ Re^{1/2}\ Pr^{1/3}$
Re = Reynolds No. = 5×10^5
Pr = Prandt1 No. = 12.99 at 273 °K
Nu = Nusselt No. = $0.664 \times (5 \times 10^3)^{1/2}\ 12.99^{1/2}$
= 110.3

$Nu = Hl / k$

Where,

h = Heat transfer Co-efficient (w / m^2 °k)
L = Length = 3 cm = 0.03 m
K = Thermal conductivity = 0.569 w / m °k
We get,
h = 2100 w / m² °k

For Air:

$Nu = 0.664 Re^{1/2}\ Pr^{1/2}$

Where,

$Re = 5 \times 10^5$
$Pr = 0.718$
$K = 0.901 \times 10^3$ w / m °k

Solving,

$Nu = 0.664 \times (5 \times 10^3)^{1/2} \times 0.718^{1/2}$
$Nu = 42$

Now, heat transfer co-efficient is found from the following relation,

$Nu = Hl / k$

Where,

h = Heat transfer Co-efficient ($w / m^2 \, ^ok$)
L = Length = 3 cm = 0.03 m
K = Thermal conductivity = $0.901 \times 10^{-3} \; w / m \, ^ok$

We get,

$$\mathbf{h = 1.2614 \; w / m^2 \, ^ok}$$

Heat transfer co-efficient for water is hundreds of time larger than the heat transfer co-efficient of Air. It means that by using a liquid as water we can remove infinitely larger amount of heat as compared to air.

Pressure Considerations

While comparing the air and liquid cooling, another factor which should be taken in account is the operating pressure. As, we move to the higher altitudes the pressure decreases and the density of air also decreases. In forced convection the cooling depends on the mass flow and at the lower density the mass flow is also lower. [6]

On the other hand, the effects of pressure change on liquids are not so adverse.

Results

Cooling Mode		Flow Volume (m^3/sec)	HTC ($w/ m^2 \, ^ok$)
1.	Water Cooling	7.92×10^{-6}	2100
2.	Air Cooling	0.0393	1.2614

Conclusions

Looking at the above discussion and results it is clear that air cannot remove enough heat from a microelectronic device. Air cooling may has some advantages over the liquid cooling but it simply will not remove sufficient heat from the more powerful-tightly configured systems that are on today's microelectronics.

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A CRITICAL REVIEW OF THE DEVELOPMENT OF A NEW EMPIRICAL NON-CUBIC EQUATION OF STATE

By

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INTRODUCTION

The purpose of this paper is the development of a new empirical non-cubic equation of state and comparing the results obtained for the test substances with the BWR and Soave-BWR equations of state. In this connection, Methane, Propane and Hydrogen were used as the test substances. As a result, a new equation was developed empirically fitting the critical isotherm of the substances under examination. The volume and temperature dependence of the parameters in the equation had been studied. In order to study the volume dependence of the parameters, a function was found which fits the critical isotherm of the test substances. A study on Temperature dependence was conducted under many sub-critical and super-critical temperatures. The least square method was used to fit the parameters as the function of temperature. Further, Enthalpy of vaporization for methane was also calculated. At the end the results were compared with BWR and Soave-BWR equations of state. The comparison was made for Pressure, Specific volume, Saturation pressure and Enthalpy of vaporization of methane and, as a result, the average % deviations had been found to be 0.38% , 0.14% and 0.66% .

BACKGROUND

An equation of state may be defined as a relationship between the state variables, such that the specifications of two state variables permit the calculation of other variables. For a real gas these variables are related to each other under ideal gas law [2].

$$P = \rho RT/M$$

As this law fails to provide the satisfactory results when applied to real gases, a large number of researchers have worked and are still working to establish a relationship in the form of an equation of state that defines the behavior of a real substance more accurately.

Vanderwaals, Peng-Robinson and SRK equations of state can be quoted here as some notable examples of the cubic equation of state, which can be used for the liquids as well as gases. The limitation of the cubic equation of state arises at high density of the liquid and gases.

The other category of EOS is the non-cubic equations of state, which are known as Virial equations and include BWR, BWRS and Soave-BWR equations of state.

The Virial equation of state is derived empirically yet it is noticeable that it is the only equation of state, which is justifiable on the basis of Statistical Thermodynamics. The most effective outcome of the Varial equation is BWR equation of state, which was given, by Benedict, Webb and Rubin in 1940. [2]

$$P = RT/V+(BoRT-Ao-CoT^2)\,\rho^2 + (bRT - \alpha)\,\rho^3 + a\alpha\rho^6 + CT^2\,\rho^3\,(1+\gamma\,\rho^2)\exp(-\gamma\,\rho^2)$$

Many researchers have modified this equation but the most commonly used modification is the one given by Starling in 1973. [2]

$$P = \rho\,RT+(BoRT-Ao-CoT^2 + DoT^3 - EoT^4) + (bRT - \alpha - d/T)\,\rho^3 + \alpha\,(a + d/T)\,\rho^6 + CT^2\,\rho^3\,(1+\gamma\,\rho^2)\exp(-\gamma\,\rho^2)$$

The density dependence of the BWR is retained in BWRS, while the temperature dependence of the co-efficients was changed. It is important to note that Simplicity is not among the good quality of both equations.

The researchers have always been looking to develop an equation of state, which has a lower number of parameters that is easy to use and is accurate. If the equation of state is simple, there will be a less number of parameters, which means lower accuracy. However, a reasonable accuracy may be achieved by properly choosing the equation of state even if the equation has a lower number of parameters. [2] [3]

In order to determine the values of the co-efficients a particular procedure has to be followed. The values can be determined either by fitting data for the substance under consideration, or by the calculation from the mixing rules. Once the co-efficients are known, all the state variables can be calculated from the known variables. The practical purpose of an equation of state is to provide easy and effective way to calculate the enthalpy, entropy and PVT data for different substances and applying this data to obtain effective and energy saving processes and apparatus. [2] [3] [4]

Critical Review :

The new developed equation of state is given as follows. [1]

$$P = RT / V + B_o / V^2 + C_o / V^3 + D_o / V^6 + E_o / V^2 + F_o \exp(G_o V)$$

This education has lesser number of parameters as compared to the BWR and Soave-BWR equations. A unique thing noticed here is the volume function in the exponent of the last term is in the numerator while in all other non-cubic equations of state, this function is in the denominator.

The first step in the development of the new equation of state is the determination of volume dependence of the parameters in the new equation of state. This proceeded by finding out a function, which fitted the critical isotherm for the test substance. It is claimed by the authors that the best results were obtained by fitting a simple reference function to the critical isotherm. It has not been explained that what other forms were considered and why they could not be used for this equation. Moreover, the paper does not explain anything about the procedure used to find out this function or any assumptions made. The significant point about fitting the critical isotherms was the enforcement of Vander-Walls conditions ($\gamma p/\gamma v=\gamma^2 p/\gamma v^2=0$) at the critical points. The methods used for applying these conditions are well defined in the paper.

The used of alternative repulsive term for the new equation of state is also explained well in the paper. The first term in the equation of state accounts for the repulsive term and it was replaced by three alternative versions.

1. Van der Waals hard sphere term.
2. Co-volume parameter.
3. Scot hard sphere term.

They were then fitted to the critical isotherm of methane and best results were obtained using the new equation of state, which shows effectiveness of the new equation, but these improvements are only shown for methane rather than all three-test substances i.e., Methane, Propane and Hydrogen. The reader is unable to judge the validity of equation for other two test substances, which is a serious error in terms of the representation of data in this paper.

In the next section of the paper the temperature dependence of the parameters of the new developed equation of state is determined. The authors choosed three temperature dependent parameters. However, it has not been explained that why these three parameters were chosen. The temperature of these parameters is given by the equations (3), (4) and (6) in the paper, but again no steps are shown how these equations were generated. [1]

In order to calculate the saturation pressures and saturation volumes the authors had derived the following fugacity equation. [1]

$$\ln \varphi = 2B_o/RTV + {}_{co}/2RTV^2 + 6D_o/5RTV^5 + 7E_o/6RTV^6 + (G_oV-1/G_oRT)\, F_o \exp G_o (V) + \ln z$$

Again, the final equation has been presented in the paper but no derivation of this equation has been shown. There are no assumptions in order to use this equation for the real systems i.e., range of temperature and pressure at which this equation works. The values of the parameters for new equation of state for methane had been calculated and listed in table 1. It is stated in the paper that these values were obtained at different temperatures and pressures but no range of temperature and pressure is given in the paper.

The enthalpy of vaporization was also calculated in this paper. The following expression has been used for this purpose. [1]

$$H^{dep}=H^{ideal} - H = -(Bo + \beta) / V - (Co + \gamma) / 2V^2 - (Do + \delta) / 5V^5 - 7Eo / 6V^6 + (1 - Go\, V) / Go\, Fo \exp Go\, (V)$$

The derivation of this equation has not been shown in the paper. The final equation is presented in the paper. Value of enthalpy of vaporization for the test substances are not calculated. In the last section of the paper the results obtained by using the new equation of state are compared with the already published Soave-BWR and BWRS equations of state. The paper shows consistency in terms of method used to generate data for all three equations under comparison. The comparison shows that Soave-BWR equation of state still gives better result than the new developed equation of state in most cases. This is a question mark on the validity of the new equation of state.

It has been stated earlier in the introduction of the paper that the new non-empirical equation of state is applied to propane, methane and hydrogen, but as a matter of fact, the reported calculations and the data is meant only for methane. The new equation is developed for the pure substances and no mixing rules have been developed for this new equation of state, which means that it cannot be applied to the mixtures. This is a serious drawback in the application of new equation of state to the real life problems. The authors compared the new developed equation of state with already existing equation of states (BWR, BWRS and Soave), which can be applied to pure substance as well as mixtures.

Like all conventional equations of state this equation has the problem of fitting the pure substance data near the critical point and the errors shown in the fig.1 are large near introduced a near-critical correction term for this new non-empirical equation of state [6]. This near critical-correction factor gives significant improvement for methane.

Conclusions

The new developed equation of state is simple than both BWRS and Soave-BWR equation of state, which means that it is easy to apply. The work done in the paper can be quoted as incomplete since the new equation has not been applied to all the three-test substances. The derivations of the equations are not shown in the paper. The new developed equation of state cannot model mixtures. Overall, this paper is a good base for future work, though it is not free from certain deficiencies as explained above. A lot of work is yet to be done in order to show the superiority of this new equation of state over the already published equation of states. This can be done by applying this new equation of state to other pure substances and comparing the results with the already published equations of state. Further research work may be pursued to develop the form of the equation that can be applied to the mixtures by developing mixing rules.

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25

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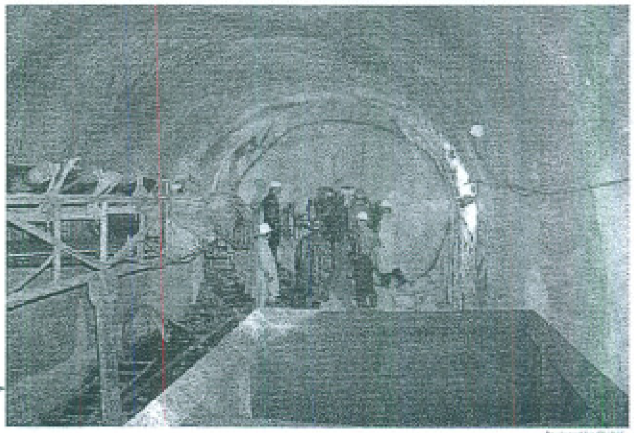

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