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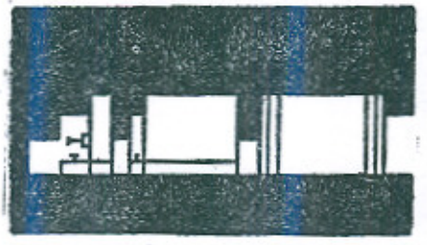
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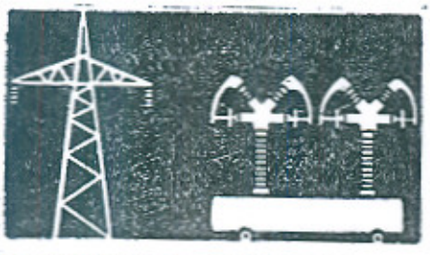
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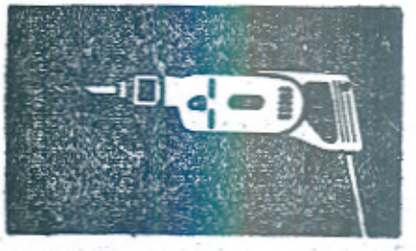
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MAL



Groundwater Engineering Need of the day

West Pakistan now diverts 83.5 maf. of water from its rivers.

This achievement is a result of strenuous efforts of Irrigation Engineers, extending over almost one hundred years. At present we can irrigate about 40 million acres of culturable lands of the Indus Plains. Still, West Pakistan possesses another 32 m. acres of culturable areas for which so far no irrigation water is available.

The water which is actually utilized by crops after conveyance losses, is hardly 41 maf. In fact, about 14 maf. is lost between the outlets and the fields. Presently (1965), this diversion includes about 2.0 maf. of water pumped out of groundwater. In fact, from the diversion of 83.5 maf. to the outlets about 33.5 maf. is lost, so that, at a time, crops are grown on 25 m. acres of lands only.

Mangla has started operating. We expect to have Tarbela ready by 1975. The two storages will increase the water diversion to 90.0 maf. Exploitation of groundwater is also in hand on a large scale and, by the end of this period, another 27 maf. will be drawn from this source and the net delivery to the farms will rise to about 78 maf. The crops will then utilize about 58 maf. against the present 41 maf. This will improve our water allowance to land from the low figure of 2.2 ft. per acre foot to about 3.0 ft. of water per acre foot.

Harza has estimated that our present percolation to groundwater is 36.4 maf. and it will rise to 46.2 maf. (about 64,000 cusecs) by 1975. Our losses to the sea will still remain equal to 40 maf. which is about 30% of our total surface water resources of 140 maf.

So far we are deficient in food and our annual population growth is about 2.5 per cent. We need to produce more food for which we need more water; but at present

there is no immediate prospect of conserving more water from the surface resources. The situation is no doubt difficult, but not hopeless. God gave us Pakistan, which has immense resources. It is for us to seek and utilize them.

For thousands of years water has been conserved for us. A vast reservoir of groundwater has been built up since generations. In an area of about 13.2 m. acres in the Northern Indus Plains, previously called the Punjab, and in about 2.78 m. acres of the Sind, the groundwater to a depth of 100 to 700 feet is of very good quality, with mineral salts less than 1000 ppm. In another 4.52 m. acres of the former Punjab, water of the same quality exists from 50 to 300 feet from the surface. Within an exploitable depth of one hundred feet about 300 maf. of fresh water is stored. To this a constant addition of about 46 maf. of water, seepage from our surface resources, takes place. Thus anything like 40 to 45 maf., nearly half the 1975 surface diversion, is available under our very feet. God is indeed Great. He has showered His benevolence without bounds. This gift, which at one time was considered a menace, was in fact a boon. It was for us to seek and exploit.

This resource can satisfy our requirement to a large extent, for a long time to come. Within two decades of the creation of Pakistan, the importance of this wealth became evident and now, all-out efforts are being made, by the Government Agencies and the individuals, to exploit this source quickly for the people of this land.

According to the World Bank estimate, about 20700 public tubewells and about 52,000 private tubewells will be in operation by 1975, withdrawing about 32 maf. of water. By 1985, exploitation of this source will rise to about 43 maf.

A hundred years of efforts has resulted in diversion of only 83.5 maf. or 41 maf. to the farms. Within a decade and a half we now want to increase the net crop use to 83 maf. When we compare the time at our disposal and the volume of water to be exploited, the gravity and extent of the task become apparent.

Mining is extremely difficult. One has often to grope in the dark. The extent of availability, its nature and quality, are ascertained only by complicated means. The exploitation of groundwater is similar to mining, but in our case we have started with an assumption that, drill wherever you like, you can find water to your needs.

God has led us to a source of great wealth. It is for us to exploit it, using all our intellect. However, to every action there is a reaction. Light and Darkness exist together. Godliness and profaneness have lived together, one for a bright pious life and the other to exploit our every weakness. Exploiting of groundwater is not all so bright. There is also a dark side of the problem. Saline groundwater which has been kept at bay by the fresh water, can have its comeback. Chances are great for this menace, unless we step cautiously and carefully.

We are accustomed to dig big canals, divert thousands of cusecs at one place. This water flows to lower elevations into our fields without much effort, but in case of groundwater one has to collect one to three cusecs spread on extensive areas. Each unit of exploitation is a mechanical device deserving our special care and attention. Naturally, exploiting of this source is not so easy.

For a diversion of about 80 maf. we have a vast organization, with thousands of

workers engaged on different jobs. The Irrigation Secretariat alone constitutes eight Chief Engineers, forty Superintending Engineers, 150 Executive Engineers, 400 Sub-Divisional Officers and a vast multitude of ancillary staff.

The Agricultural Development Corporation has a Chief Engineer and Irrigation Adviser, three Deputy Chief Engineers and several other Superintending, Executive and Sub-Divisional Officers.

Similarly, Wapda has an important Surface Water Wing. Practically all these persons are engaged to exploit 83 maf. of water. These organizations are well established.

During the last one hundred years, we have collected a wealth of knowledge of procedures, designs and construction. Books like Manual of Irrigation Practice and innumerable contributions are available for guidance on maintenance of Irrigation Works and their constructional methods.

All these facilities are available for surface water diversion. Now we are aiming at doubling the water quantity at the farms. One half is to come from the underground source. Have we ever reckoned the facilities for this exploitation?

The Irrigation Department has set up only two Circles. They are to construct and to operate tubewells. There are hardly two Circles of Agricultural Department and two Chief Engineers of Wapda, with their staff, engaged on construction which is not the end of exploitation. It is the operation and continued long-term yield of water which is the real problem. This we will face at the time of operation.

The present system of exploitation has no established and tried rules of design, no set principles, no manuals and no guides. Above all, there is no practical experience of operation.

In West Pakistan, of 50 million persons, there is not a single institute or organization imparting knowledge and training in this specilised subject.

The University of Engineering and Technology, Lahore, which is the oldest Institution of the country training future Engineers, has only recently introduced Irrigation engineering as a subject. The groundwater course is a small fraction of the syllabi. It is doubtful whether any of the other three Engineering Universities or the Agriculture University, training Agriculture Engineers in this part of the country has better facilities in this specialised branch.

So far we are working on some thumb rules known only to a small group of Engineers who have gained this specialised information more from the mistakes than from the actual study of the subject and training.

In fact, the very means of attaining and acquiring this specialised knowledge does not exist in this country. There are no manual on tubewell practices. There is no book on design. The Irrigation Department, the Engineering Institutions, have no facilities of training.

Now let us look at the Scientific side of the problem. It is our object to recover a large portion of 46 maf. of seepage and mine out of 300 maf. of groundwater storage, all to be utilized properly on about 40 m. acres of land.

What are our Scientific Institutions engaged on investigations? Where are our qualified and trained Scientists and Engineers for the solution of problems of land and water?

If we have to successfully achieve our object we need thorough planning. Tube-well installation alone is not the end of the job. Operation, and operation without trouble for a long time to come, is the object of developing this source of water. We want immediately a large number of Irrigation Engineers to handle the problem of construction and exploitation of groundwater. We need to create facilities for training in this specialised subject of groundwater engineering.

A Research Organization equal to the extent of the problems, staffed with specialised, trained personnel, is as essential as the above two items. Preparation of Manuals, Charts, Books on the subject of Groundwater and Irrigation Practice is of equal importance for the guidance of the young Engineers.

Like a developing nation, we must move with the times and the circumstances, if we have to maintain an honourable existence in the vast developing world of today.

Let those who are in a position to command and to guide ponder over the subject. Time is fast approaching when another menace of deteriorated soil, change of good quality groundwater into saline water and other problems far more acute than the present waterlogging and salinity are bound to appear. If not looked at, and taken care of, in time, these problems will become far more acute.

Chemical Characteristics of Soil for Cotton Growth

By CH. MUHAMMAD HUSSAIN,
Director, Land Reclamation, West Pakistan

This article by Ch. Mohammad Hussain discusses the effects of soil characteristics, its alkalinity and salinity status on the yield of cotton crop. As a result of experiments conducted at nine different sites in West Pakistan, it has been established that for optimum yield of cotton, the pH should always be less than 8.5 and total soluble salts should be less than 3.4 mm./cm. The excess presence of Calcium plus Magnesium over Sodium is another useful factor for high yield. High percentage of Chlorides, however, seriously affects the yield.

The article gives a very useful and comparative information on the optimum yield of cotton in Ghotki areas as compared to Rahimyar Khan.

INTRODUCTION

The importance of cotton is well known all the world over. In Pakistan it is the major fibre crop along with jute. In West Pakistan out of a total cultivated area of 46 million acres the area under cotton crop during 1965-66 was 3.86 million acres and the total production was 2.33 million bales. Since cotton next to jute is the important source of foreign exchange earning, efforts are being made to boost the production by increasing the area under cotton and the average outturn. The target fixed for the year 1967-68 is 3.0 million bales.

Cotton plant has a deep-root system. The roots of desi cotton were found to penetrate to a depth of 6 feet and those of American varieties to a depth of 6½ feet. The study of the characteristics of the soil profile is an important feature to determine the suitability of a certain land for cotton cultivation because under the same environmental conditions and equal agronomic treatments better yields are obtained from the same variety with the variation in the chemical characteristics of the soil profile. The studies[1] carried out in this Directorate in the artificially prepared soil profile of the two types, one set presenting the high salinity conditions in the top 2 feet soil strata while the other having high salinity below first two feet soil. The effect of presence of salinity in the top 2 feet of soil strata was obviously more pronounced as compared with the presence of salts in the soil profile at a depth lower than 2 feet from the soil surface.

Under low irrigation application presence of zone of accumulation of salts within the root zone at a depth of 3 to 4 feet seriously affects the opening of the cotton bolls which is called 'Tirk'. Serious losses[2] in the yield occur whenever there is 'Tirk' in the Punjab American cotton and both the seed and lint suffer in maturity and result is poor overall yield and quality.

The present paper discusses the salinity status of the soil profile in relation to growth of cotton plants and an interrelationship of the various constituents in the soil affecting the yield of the crop.

MATERIAL AND METHODS

In order to undertake these studies 9 representative sites in the following areas were selected:—

1. Ghotki.
2. Rahimyar Khan.
3. Lyallpur.
4. Jaranwala.
5. Chichawatni.
6. Dadfatiana (Sahiwal).
7. Khanewal.
8. Khairpur.
9. Larkana.

In the Ghotki and Rahimyar Khan area the fields selected were those where cotton was grown normally and there were no visible signs of salinity anywhere in the fields. Normal irrigation and agricultural practices were also carried out. The sampling was done in the months of October and November, 1966 and the samples were collected up to a depth of 9 feet with one foot interval. The analysis was carried out in respect of detailed chemical constituents like Ca, Mg, Na, CO_3, HCO_3, Cl and SO_4 present in the soil extract. The fertility constituents like phosphorus and potassium were also determined. SAR was also computed. The methods followed were generally those given in U.S.D.A. Hand Book 60[3].

In case of other sites the following 4 types of fields were selected in each area:

1. Good fertile land having good growth of cotton plants.

2. In addition such fields were selected where patches of salines were visible at the soil surface. These fields had also some good portions where normal growth of cotton was observed. In the salt affected portion of the field the growth of the plant was patchy and stunted and many such saline pockets were completely devoid of vegetation. Soil samples from such fields were collected from the three sites depicting the following conditions:—

(*i*) Good portion of the field having normal growth of crop.

(*ii*) Portion of the field with thin and stunted growth of cotton plants.

(*iii*) Portion of the field where cotton failed to germinate or establish.

Samples from these portions of the fields were collected up to a depth of 5 feet with one foot interval in the months of October and November, 1966. The samples were analysed for pH and salinity in millimhos/cm. by the usual methods.

RESULTS AND DISCUSSION

(*a*) Tolerance of crop to salt and alkalinity

Amongst the fibre plants, the cotton varieties commonly grown in U.S.A. are considered very salt tolerant and it has been reported that cotton makes good growth under conditions of high salinity in the range of 0.4 to 0.6% salts. 0.25% salts concentration is stated as safe limit for root penetration without injury.

The results of soil analysis from different sites of cotton growing tracts of the Province

FIG. A

RELATION BETWEEN pH, CONDUCTIVITY & GROWTH OF COTTON IN VARIOUS REGIONSOF WEST PAKISTAN.

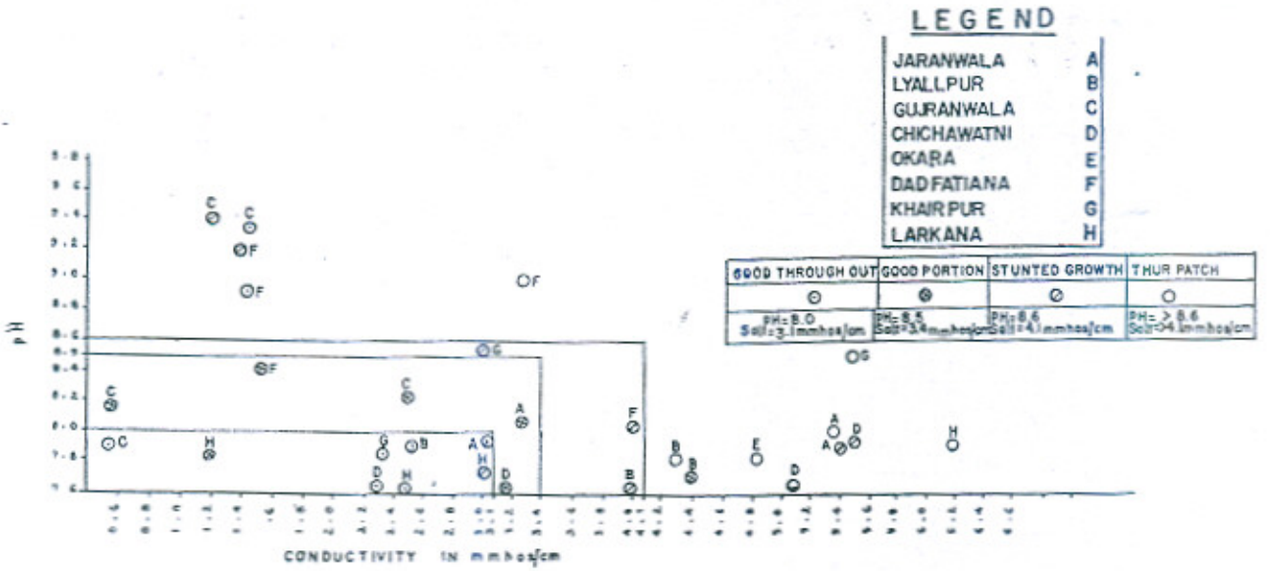


Fig. B



Bumper growth of Cotton in Ghotki area.

TABLE NO. I.—*Analysis of Ghotki area on the left bank of Guddu Barrage*

Depth	Ca	Mg	Na	CO_3	HCO_3	Cl	SO_4	Total cations/ anions	Ec × 10^3 at 25°C	pH	SAR	Moisture equi-valent	Satura-tion percent-age	P_2O_5	K_2O	Crop
0′—1′	18.20	17.80	6.00	—	6.00	5.00	31.00	42.00	4.2	8.2	1.41	23.44	41.0	0.159	0.936	
1′—2′	15.20	14.80	8.00	—	4.00	5.00	29.00	38.00	3.8	8.3	2.06	28.80	45.0	0.153	0.936	
2′—3′	10.80	9.20	6.00	—	3.00	5.00	18.00	26.00	2.6	8.2	1.89	31.36	52.5	0.136	0.936	
3′—4′	16.90	23.10	3.00	—	3.00	9.00	21.00	43.00	4.3	8.2	0.60	33.18	55.0	0.138	0.842	
4′—5′	8.45	33.55	8.00	—	2.50	12.00	35.50	50.00	5.0	8.25	1.88	33.43	60.0	0.151	1.123	Cotton
5′—6′	18.20	22.80	9.00	—	2.50	15.00	32.50	50.00	5.0	8.2	1.98	32.61	58.5	0.147	0.936	
6′—7′	9.10	35.90	7.00	—	3.00	20.00	29.00	52.00	5.2	8.15	1.50	30.00	50.0	0.136	1.030	
7 —8′	27.80	20.20	12.00	—	4.00	32.00	24.00	60.00	6.0	8.2	2.45	30.52	50.0	0.151	1.123	

TABLE NO. II.—*Analysis of Rahimyar Khan area in Chak 136/P Sadiq Canal*

0′—1′	12.00	7.00	14.00	—	4.00	21.00	8.00	33.00	3.30	8.22	4.54	12.63	29.00	0.170	0.749	
1′—2′	6.00	4.00	17.00	—	3.00	14.00	10.00	27.00	2.70	8.32	7.60	15.43	30.00	0.168	0.749	
2′—3′	8.40	6.60	20.00	—	2.00	21.00	12.00	35.00	3.50	8.02	7.30	25.92	41.00	0.172	0.842	
3′—4′	7.20	7.80	21.00	—	2.00	23.00	11.00	36.00	3.60	8.00	7.66	31.56	52.50	0.151	1.123	
4′—5′	12.00	10.00	23.00	—	2.00	27.00	16.00	45.00	4.50	5.95	7.93	29.34	47.50	0.165	0 562	Fallow
5′—6′	9.60	10.40	22.00	—	2.00	23.00	17.00	42.00	4.20	7.90	6.95	24.36	40.00	0.127	0.562	
6′—7′	10.80	15.20	20.00	—	2.00	25.00	19.00	46.00	4 60	7.95	5.94	22.95	40.00	0.144	0.936	
7′—8′	6.00	4.80	13.00	—	2.00	12.00	10.20	24.20	2.42	8.12	5.59	12.07	28.00	0.142	0.374	
0′—1′	5.00	3.00	11.00	—	4.00	13.00	2.00	19.00	1.90	8.00	5.50	16.19	31.00	0.161	0.749	
1 —2′	4.00	3.00	8.00	—	3.00	10.00	2.00	15.00	1.50	8.12	4.27	18.79	32.00	0.145	0.936	
2′—3′	5.00	4.00	6.20	—	3.00	11.00	1.20	15.20	1.52	8.15	2.91	20.10	34.50	0.151	0 749	
3′—4′	5.20	3.50	10.00	—	3.00	12.00	4.00	19.00	1.90	8.10	4.71	11.48	28.00	0.134	0.665	
4′—5′	4.00	3.50	9.00	—	4.00	11.00	1.50	16.50	1.65	8.06	4.64	14.67	30.00	0.122	0.665	Sugarcane
5′—6′	4.50	4.00	10.50	—	3.00	14.00	2.00	19.00	1.90	8.05	5.07	11.03	27.50	0.148	0.665	
6′—7′	4.50	3.50	5.00	—	2.00	8.50	2.50	13.00	1.30	8.18	2.50	11.19	27.50	0.175	0.665	

of West Pakistan as graphically illustrated in Fig. A, show that—

(*i*) 85% of the plots showing good uniform growth fall within the range of 8.5 as pH and the salinity of the extent of 3.4 millimhos/cm. The ideal conditions for the fertile fields showing good growth and good yield are pH 8.0 and the salt content 3.1 millimhos/cm.

(*ii*) Crop showed patchy and stunted growth in the soils with pH in the range of 8.5 to 8.6 and the salt content 3.4 to 4.1 millimhos/cm. Nearly 50% of the fields visually observed fall within this range.

(*iii*) Cotton crop practically failed to establish in the soil having pH above 8.6 regardless of very low salt content. Similarly the cotton plant failed to establish or showed poor and stunted growth when the salt exceeded the limit of 4.1 millimhos/cm. in spite of the fact that alkalinity (pH 8.2) was quite low and within the permissible limit.

From the results of this study it can be safely concluded that for normal growth of the cotton varieties grown in this part of the Province, the soil with alkalinity beyond a limit of 8.5 as pH will have inhibiting effect on yield and so will be the case when the salines increase the limit of 3.4 millimhos/cm.

(*b*) Response of the crop to the various chemical constituents

In addition to the observations on the tolerance of this crop to salt and alkalinity independently efforts were made to establish the safe limit for different cations and anions conducive for good growth of plants, good boll bearing which results in high yield. The analysis results of two profiles, one from Ghotki pertaining to the high yielding area and the other from Rahimyar Khan tract for low yields are given in Tables Nos. I and II.

From the study of the analysis results it is noticed that there is not much difference in the constituents which attribute to the fertility values of the soil *viz*. P_2O_5, K_2O. From the moisture equivalent and saturation percentage it is, however, inferred that the Ghotki profile of moderately fine texture is uniform throughout its depth whereas the profile of Rahimyar Khan area represents the conditions of light soil.

The Ghotki tract is an ideal for cotton growth due to special physico-chemical characteristics of the soil profile.

The presence of the important soil constituent Ca+Mg in sufficient amount in contrast to Na keeps the soil in good granular structure. The SAR value of the soil profile is less than 2 and the Ca+Mg is present in the order 15.58 me/l and 22.17 me/I respectively while Na is 7.37 me/l. The salinity is also within the permissible limits, less than 4 millimhos/cm throughout the depth of the soil profile. The average yield from a block of 100 acres was about 22 maunds per acre in Kharif 1966.

The soil profile from the Rahimyar Khan tract which is known for low yield of American cotton present a different picture. The Ca, Mg and Na content is in the order of 6.28, 6.02 and 14.0 me/l respectively, the overall SAR value being 5.45. Besides that Cl content is 16.37 me/l which is fairly excessive in contrast to 7.9 me/l of SO_4. In case of Ghotki profile the Cl is 7.2 me/l and SO_4 is 26.9 me/l in the major root zone of first five feet. From this it is quite evident that for the good growth and yield of the cotton crop the soil profile must have Ca above 15 me/l and the Cl content not more than 7 me/l. Presence of SO_4 in the larger quantity to the extent of 23 me/l has no visual inhibiting effect so long as the total salinity

does not exceed 4 millimhos/cm.

METHOD OF CORRECTION

In order to obtain high yield of cotton in any part of the province climatically suitable for its growth, it is essential to correct the soil condition for the elimination of inhibiting factor. By similar studies the methods for the correction of soil for citrus growth[4] were established and used in a tract where the citrus plants were decaying. Very successful results were achieved which have since been published. Measures for the amelioration of soil constituent for cotton growth have given promising results in Rahimyar Khan area. The soil was treated with Superphosphate, Ammonium sulphate and Calcium sulphate. The dose so worked out for this soil was 110 lb. (a bag) of Superphosphate, 200 lb. (2 bags) of Ammonium sulphate and 660 lb. (6 bags) of Calcium sulphate per acre.

The combined application of the fertilizer and the amendments was made in two parts at two stages. Half the quantity was applied at the time of first Irrigation application to the cotton plants after sowing and the 2nd application of balance dose at the time of 2nd irrigation. The dressing was done close to the plants on either side of the rows with the help of pore plough.

The treated plots so far have given almost double the yield of untreated plots of the cotton picked up to the end of November, 1967. The expected outturn from the treated plots is about 20 mds. per acre as compared to about 8-10 mds. per acre from the untreated plots.

ACKNOWLEDGEMENT

The author acknowledges with thanks the assistance rendered by M/s. Nur-ud-Din Ahmad and Mohd Altaf Hussain in analysing the soil samples.

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Wapda's Water Development Projects

By ASRAR AHMAD QURESHY, M.I.E. (Pak.)
Director, Development Projects (Water)
WAPDA, Lahore

West Pakistan Water and Power Development Authority is an autonomous body developing the vast natural resources of the country. It has thus two broad divisions for Water and Power resources. Besides these two responsibilities, she has been entrusted to complete the Indus Basin works. She is also to plan and undertake measures for the reclamation of waterlogged and saline lands.

In this interesting and informative article, Mr. Asrar Ahmad Qureshy, Director, Development Projects has given an outline of the projects, both completed or under execution, since the authority came into being.

The Authority

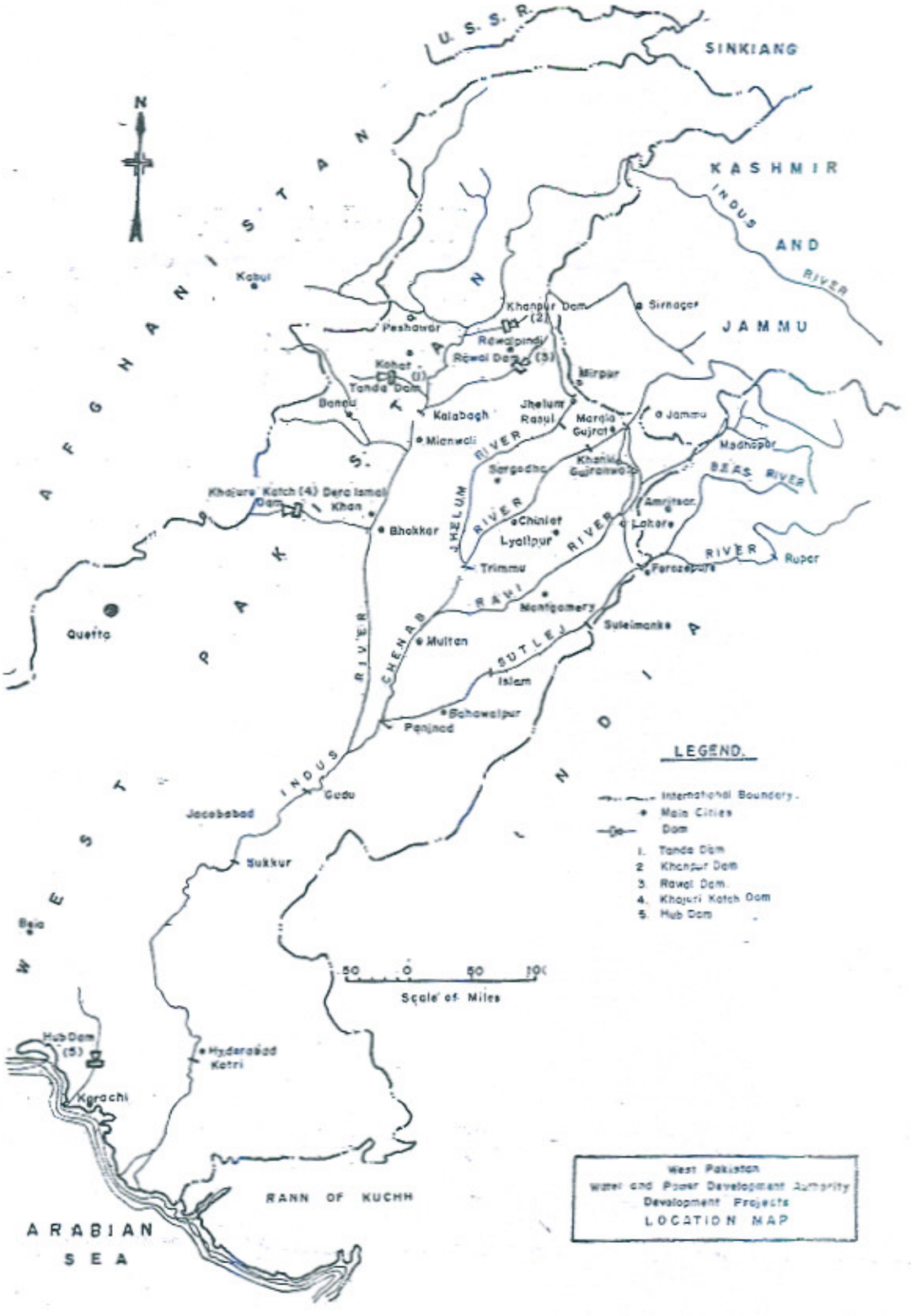
The West Pakistan Water and Power Development Authority generally known as WAPDA was set up by the Government of West Pakistan by an ordinance issued in February 1958. This ordinance was repealed and replaced by an Act of the Provincial Legislature published in the Gazette on 24th April, 1958. It was amended by a notification on 27th March, 1959, to enable the Government to transfer the Electricity Department to WAPDA.

The WAPDA was established to provide for the unified and co-ordinated development of the water and power resources of West Pakistan. The general powers and duties of the Authority are given in Chapter III of the Act, which also serves the Authority as its Charter.

Guidelines of Duties

The Authority is entrusted to investigate, survey, plan and execute schemes for all or any of the following matters:

(*i*) irrigation, water-supply and drainage; and recreational use of water resources;
(*ii*) the generation, transmission and distribution of power; and the construction, maintenance and operation of power houses and grids;
(*iii*) flood control;
(*iv*) the prevention of water-logging and reclamation of water-logged and salted lands;
(*v*) inland navigation; and
(*vi*) the prevention of any ill effects on public health resulting from the operations of the Authority.


U. S. S. R.
SINKIANG
KASHMIR
INDUS AND
RIVER
JAMMU
AFGHANISTAN
PAKISTAN
INDIA
WEST
N
Kabul
Peshawar
Khanpur Dam (2)
Rawalpindi
Rawal Dam (3)
Sirnagar
Kohat (1)
Tanda Dam
Mirpur
Banu
Kalabagh
Jhelum
Rasul
Marala
Gujrat
Jammu
Mianwali
JHELUM RIVER
Sargodha
Madhopur
Khanki
Gujranwala
BEAS RIVER
Khajuri Kotch (4) Dera Ismail Khan
Dam
Amritsar
Chiniot
Lahore
Bhakkar
Lyallpur
RIVER
RIVER
Trimmu
Ferozepure
Rupar
RAVI
Montgomery
Sulemanke
Quetta
Multan
SUTLEJ
CHENAB RIVER
Islam
Bahawalpur
Panjnad
INDUS
Gudu
Jacobabad
Sukkur
Bela
Hub Dam (5)
Hyderabad
Kotri
Karachi
RANN OF KUCHH
ARABIAN
SEA
LEGEND.
International Boundary
Main Cities
Dam
1. Tanda Dam
2. Khanpur Dam
3. Rawal Dam
4. Khajuri Kotch Dam
5. Hub Dam
50 0 50 100
Scale of Miles
West Pakistan
Water and Power Development Authority
Development Projects
LOCATION MAP

In addition the Authority may act as an agency of the Government of West Pakistan or the Government of Pakistan to exercise technical supervision, and administrative and financial control over any scheme or project entrusted to it in respect of the matters enumerated above.

As evident from the name, WAPDA consists of two separate independent wings known as the Water Wing and the Power Wing. The Power Wing is headed by a General Manager, Power, assisted by a number of Regional Chief Engineers and is responsible for the planning, designs, construction of Power Projects and generation and transmission of power. The Water Wing consists of four Divisions each under a Chief Engineer. Each Division is responsible for planning, design and execution of projects related to their wing. These four Divisions are as under:—

(1) Development and Machinery Pool Organization Division.
(2) Reclamation and Administration Division.
(3) Water, Soils and Investigation Division.
(4) Indus Basin Projects Division.

This article is, however, confined to the Water Development Projects under the administration of Chief Engineer Development and M.P.O.

Development Projects

The Projects which are financed from Pakistan's own resources are termed as "Development Projects" and distinct from the foreign-aided Indus Basin Projects. The following are some of the Development projects undertaken by WAPDA, since it came into being.

(1) Shadiwal Hydel Project. Completed in 1961
(2) Rawal Dam Project. Completed in 1962
(3) Chablat Kas Irrigation Scheme. Completed in 1963
(4) Guddu Barrage Project. Completed in 1963
(5) Gujranwala Hydel Project. Completed in 1963
(6) Tanda Dam Project. Completed in 1966 (Inaugurated in 1967)
(7) Khanpur Dam Project. Under Execution.
(8) Hub Dam Project (Known as Karachi Irrigation Project). Under Execution.
(9) Gomal Zam Multipurpose Project. Under Execution.

Of the above, the first six have since been completed and the rest are under construction. However, a brief description of each project would be of some interest to the readers.

Shadiwal Hydel Project

The Shadiwal Hydel Power Station is located on Upper Jhelum Canal at a distance of two miles from the village Shadiwal and seven miles from the city of Gujrat. It was completed in 1961. This project was undertaken to supply power to tubewells installed for fighting the deadly menace of water-logging and salinity and to increase the efficiency of the West Pakistan Power Grid.

This project was financed by the Canadian Government under the Colombo Plan. The hydel station with an installed capacity of 13,500 kw has two generators of 6,750 kw each, driven by 9,000 H.P. Kaplan type adjustable blade turbines. There is a bank of four single phase 11/132 KV transformers to step up alternator terminal voltage of 11,000 volts to 1,32,000. A five mile 1,32,000 volt transmission line has been provided to feed this supply into the main power grid at Gujrat.

The total cost of the Project is Rs. 40.12 million.

Rawal Dam Project

The Rawal Dam is located on the Murree-Islamabad road about 8 miles from Rawal-

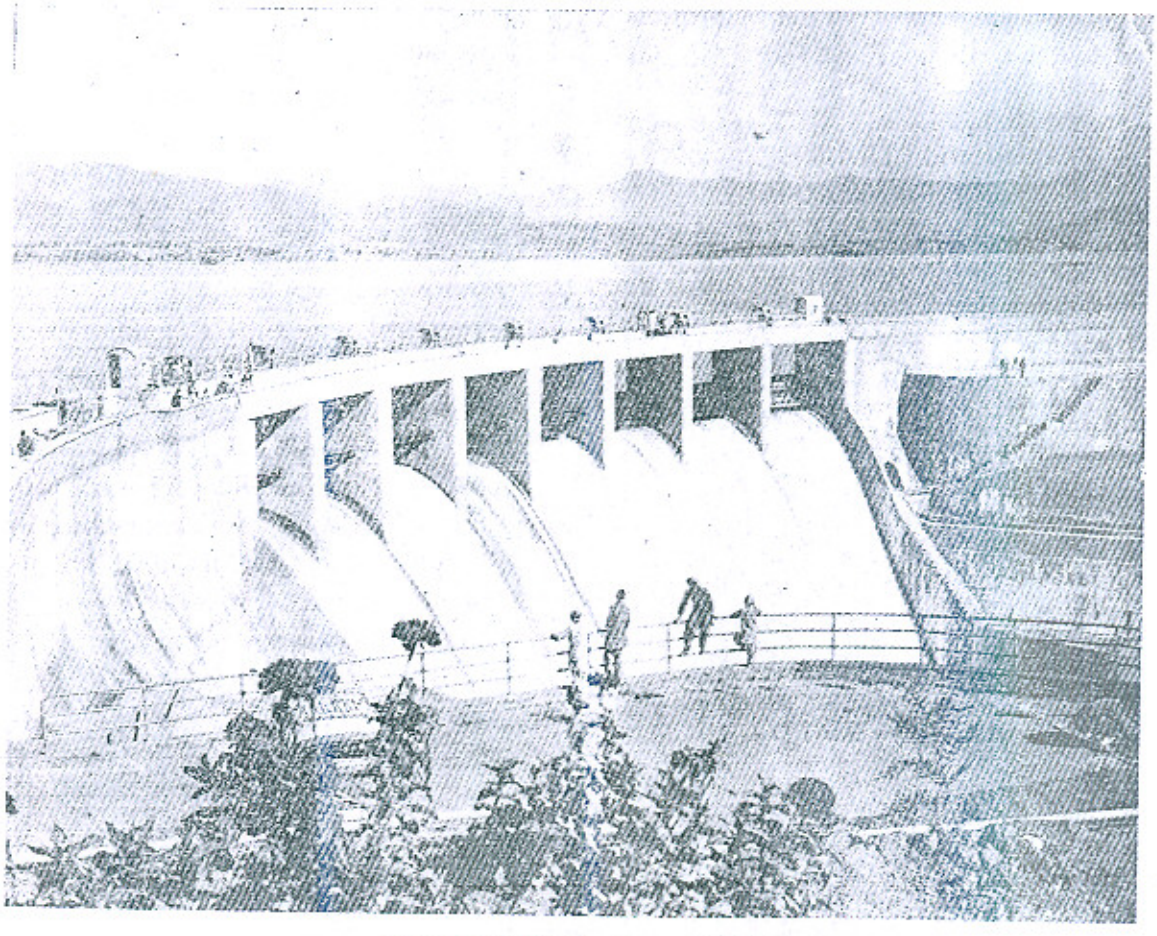
pindi. It is the first major Project undertaken by WAPDA in the Federal Capital area of Islamabad and was completed in 1962. It is a masonry structure 700 feet longs, 80 feet high from the river bed, built across the Korang river. Originally it was intended to provide potable water supply of 16.5 million gallons per day plus an annual irrigation of 12000 acres. Later on water supply has been revised to 14.00 million gallons per day and irrigation area reduced to 2000 crop acres annually as Capital Development Authority has acquired large tracts of land out of irrigable area. It has a storage capacity of 47,500 acre feet at full reservoir level.

It was designed and constructed by Pakistani engineers and contractors without any external financial aid. The total cost is Rs. 21.00 million and was completed out of Pakistan's own resources.

It has eight electrically controlled Radial type 10 feet high and 30 feet wide steel gates. The spillway of this dam is Ogee shaped with a capacity of 82,000 cusecs designed for a maximum flood of 1,20,000 cusecs.

Chablat Kas Lift Irrigation Scheme

The Chablat Kas Lift Irrigation Scheme is located about 3 miles from Hasanabdal, Campbellpur district, along both sides of the Grand Trunk Road and the main Railway line between Rawalpindi and Peshawar. This scheme was completed in 1963. It is a



Rawal Dam Project on completion.

small irrigation project and aimed at providing lift irrigation to about 1500 acres of land. There are four units with total capacity of 11 cusecs. The width of the intake channel is 10 feet. The length of the left delivery pipe is 1,150 feet with 18" dia and its discharge is 8 cusecs. The length of the right delivery pipe is 1,010 feet with 12" dia and its discharge is 3 cusecs. There are two canals named Northern Canal and Southern canal. The former is 1,430 feet long and its capacity is 3 cusecs and the latter is 16,000 feet long with a capacity of 8 cusecs.

The total cost of the Project is Rs. 3.60 lacs.

Guddu Barrage Project

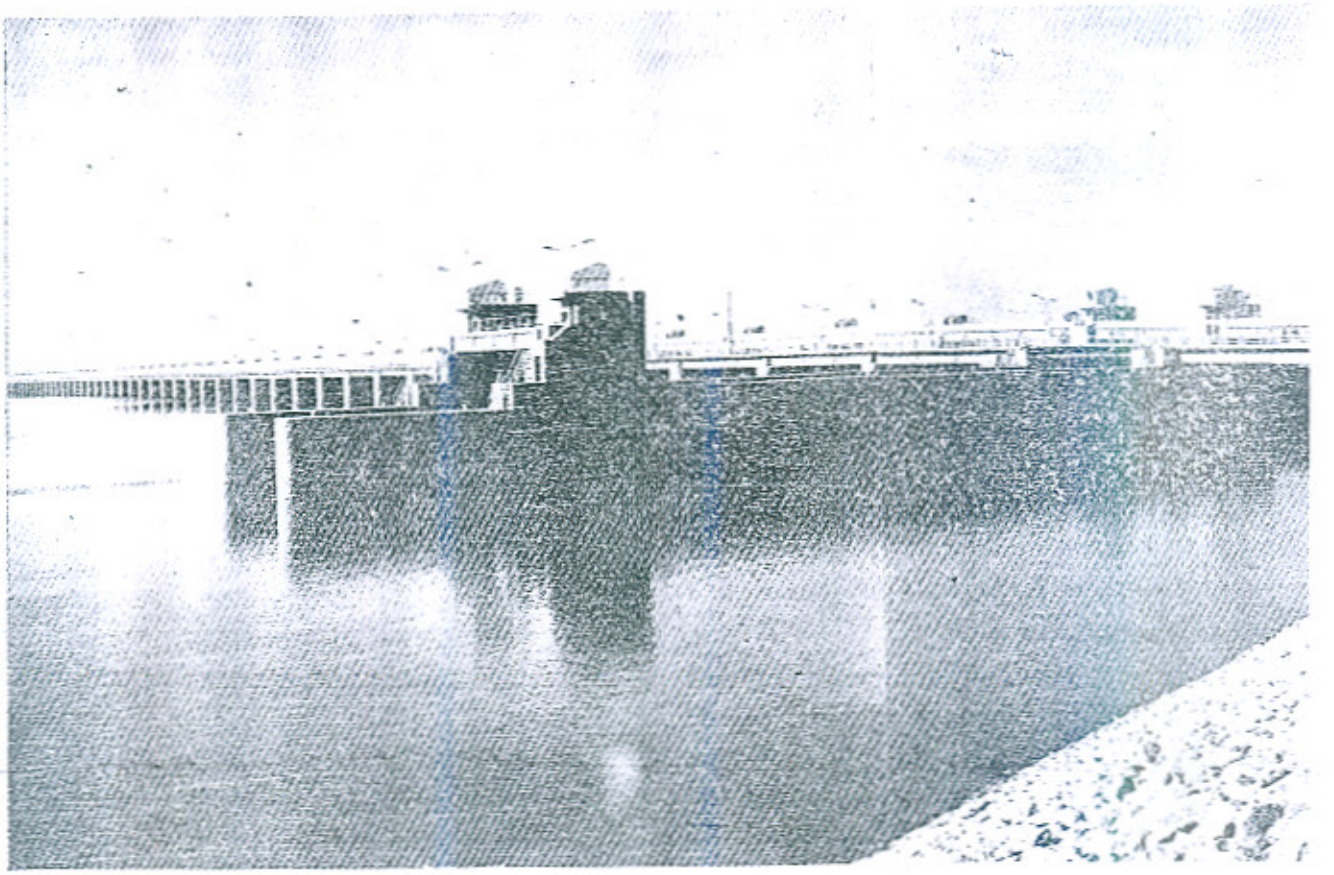
This barrage was completed by WAPDA during the year 1963. It spans the Indus near Kashmore, about 64 miles below the confluence of the Indus and the Sutlej. It has a total length of 4,445 feet between abutments and is capable of passing a peak flood of 1.2 million cusecs. It consists of 64 spans of 60 feet each, one navigational lock with a span of 50 feet, and two long divide walls with a fish ladder in each.

After the integration of West Pakistan, the culturable commanded area was increased from 2.3 million acres to 2.87 million acres, including 2,23,000 acres of forests. The new weir-controlled canals have been designed to give an assured supply of water not only to the area previously dependent on inundation canals but also to new areas.

There are two Right Bank canals: (1) Desert Pat Feeder and (2) Begari Sind Feeder and one Left Bank canal, Ghotki Feeder.

Desert Pat Feeder

This feeder is 7 miles long with a discharge capacity of 13,140 cusecs. After 7 miles, it splits into two main feeders, one to serve the area of the old Desert Canal and the other



Guddu Barrage.

named Pat Feeder, to irrigate mostly the virgin soil in the Nasirabad Tehsil. The length of the dependent remodelled canals of the Desert and Pat system is 423 miles while the length of new canals in the Desert and Pat network will be 65 and 210 miles respectively.

Begari Sind Feeder

This feeder is 80 miles long with a discharge capacity of 14,780 cusecs. The length of the dependent remodelled canals is 462 miles and new canals will be 197 miles. In addition 57 miles of new channels are to irrigate high katcha lands near the Kashmore bund.

Ghotki Feeder

This feeder is 81 miles long with a capacity of 8500 cusecs. The canals dependent on this feeder are 421 miles of remodelled channels and 306 miles of new channels.

The Right Bank canals irrigate Kashmore, Kandkot, Thal, Jacobabad, Garhi Khairo and Nasirabad talukas in Jacobabad district; Shahdadkot taluka in Larkana district, and Shikarpur, Sukkur and Garhi Yasin talukas in Sukkur district. The Left Bank canals irrigate Rohri, Pano Akil, Ghotki, Mirpur Mathelo and Ubauro talukas in Sukkur district.

This project also involves the construction of 589 regulators of various sizes, 803 road bridges including bridges over cross regulators on feeders, branches, sub-branches, distributaries and minors, 36 railway bridges and 33 other miscellaneous structures like falls, syphons and aqueducts.

This project when fully completed will cost Rs. 474.8 million of which the cost of the barrage proper will be Rs. 217.3 million and that of the irrigation system including the remodelling of the existing canals, Rs. 257.5 million.

Gujranwala Hydel Project

This project was completed in 1963. It is located at Nandipur on Upper Chenab Canal about 9 miles from Gujranwala. It is generating 13,800 kw through 3 turbo-alternator units of 4,600 kw each to supply power to Tubewells of the Reclamation Projects in the Rechna and Chaj Doab. The total cost of the project is Rs. 51.10 million and was completed out of Pakistan's own resources.

The maximum and minimum head race discharge is 10,028 cusecs and 3,800 cusecs respectively to run the three turbines. It has 6 bays with a span of 21′ 9½″ each. The total output is 13,800 kw and the cost of producing power per unit is 2.5 paisa.

Tanda Dam Project

Tanda Dam is located near Kohat. It is a rolled earthfill dam, 115 feet high and 2340 feet long at the top, forming an off channel reservoir. A barrage has been constructed across Kohat Toi which diverts its water into a feeder-canal and an inlet tunnel of 10′ diameter 800 feet long to convey the water to the reservoir. Maximum discharge capacity of the inlet tunnel is 3.000 cusecs. The gross storage capacity of the reservoir is 78,400 A.F. with a live storage of 64,800 A.F. Water will be drawn from this reservoir for irrigation through an outlet tunnel providing regulated supplies of water to 32,000 acres of land in Kohat district.

An open cut uncontrolled type Spillway 30 feet wide has also been provided with a designed capacity of 1,900 cusecs to allow escape to the surplus flow of water from the reservoir.

Diversion works and main dam were completed and water successfully diverted

to the reservoir on 30th June, 1966. Outlet works have also been completed, the distribution system is in advanced stage nearly completed.

The expected life of the reservoir is 40 years. The total cost of the Project is Rs. 66.83 million and is constructed out of Pakistan's own resources.

The Irrigation water is supplied to 32,000 acres of land through a system of lined canals over 56 miles in length. With 150 per cent proposed cultivation intensity, it is expected that this area will yield 48,000 cropped acres annually. It is estimated that the annual crop output over this area will increase ten-fold and rise to about Rs. 3 crores. This will amply justify the expenditure of Rs. 6.7 crores incurred on this project.

A unique feature of this project is the fact that it has been engineered and constructed entirely by Pakistani Engineers. Tanda Dam Project has been a good training ground for future Dam-builders of Pakistan; it has given confidence to our Engineers that they can design as well as execute large Dams without importation of know-how from abroad.

WAPDA did not ask for any allocation of foreign exchange for the construction of this Dam. The Dam was constructed by the Machinery Pool Organization, from the machinery which became surplus after the completion of Ghulam Muhammad and Guddu Barrage Projects. Although hauls up to 2 miles were involved, no new machinery was specifically purchased for the project.

Khanpur Dam Project

The Khanpur Dam Project is located near Khanpur village on Taxila-Haripur Road about 1000 feet downstream of the confluence of Nilan Kas with Haro, in Hazara district and is expected to be completed in 1970. It is a purely irrigation project for harnessing the water of Haro river for irrigation of about 1,13,000 crop acres of good fertile land in the districts of Hazara, Campbellpur and Rawalpindi.

It is designed as an earthen dam 1310 feet long and 137 feet high with a view to conserving 59,000 acre feet of water for regular supply to two canals on each side of the river with 250 cusecs and 175 cusecs discharge capacities. It will be the biggest dam so far undertaken in this region and would help meet food, dairy and other domestic requirements of the new Federal Capital at Islamabad as well as Rawalpindi.

The proposed Spillway 380 feet wide will have Radial gates with discharge chute and is designed for 1,13,000 cusecs. It has a 2,000 feet long 12 feet dia horse-shoe diversion tunnel.

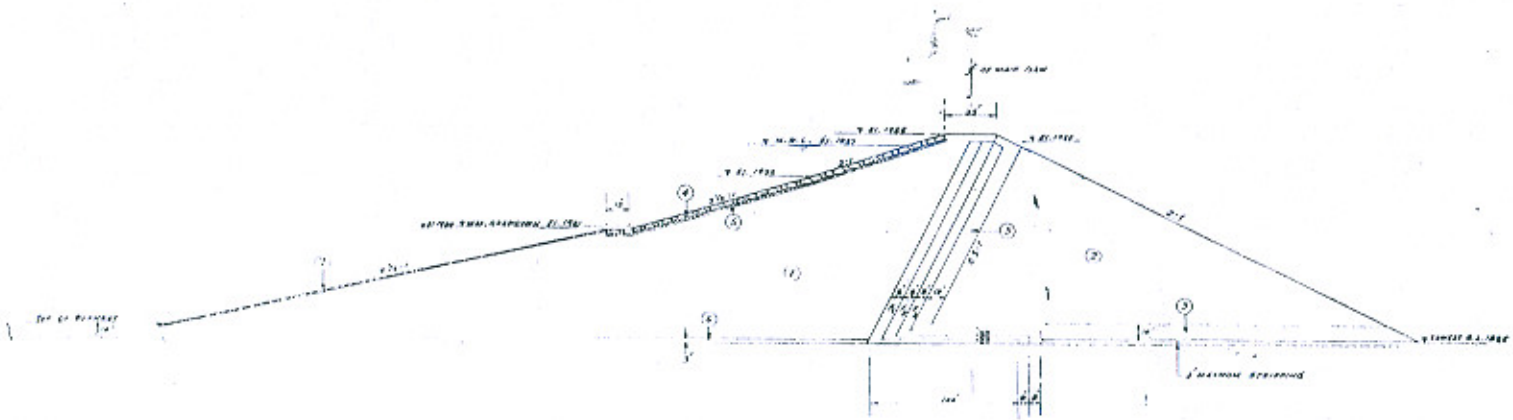
The project is estimated to cost Rs. 107.20 million and the expected life of the reservoir is 100 years.

Karachi Irrigation Project

The Karachi Irrigation Project originally known as the Hub Dam Project, is located just below the confluence of Shorin nullah with the Hub river at a distance of about 35 miles north-east of Karachi. It is expected to be completed by 1970-71. It is an earthen dam 146 feet high and 22,900 feet long and will create a reservoir of about 7,73,000 acre feet submerging some 20,360 acres of barren land. It has a catchment area of 3,410 sq. miles.

It aims at providing irrigation for 84,000 acres of cropped area yielding annually 15 million maunds of fodder, 3 million maunds of fresh vegetables, 0.85 million maunds of fruit and about 4 million maunds of sugarcane. This yield will not only ease the existing acute shortage of these essential

KHANPUR DAM PROJECT



PROPOSED COMPOSITE SECTION
MAIN DAM
SCALE : 1" = 30 FEET

LEGEND :

(1) IMPERVIOUS FILL - CLAYEY SILT FROM BORROW AREAS ROLLED IN 6" LAYERS

(2) RANDOM FROM SPILLWAY EXCAVATIONS, DUMPED & COMPACTED WITH VIBRATORY & PNEUMATIC ROLLERS.

(3) SELECTED RANDOM FILL - MAXIMUM D_{15} SIZE NOT EXCEEDING 6"

(4) DUMPED RIPRAP - SELECTED STONES, AT LEAST 50% GREATER THAN 250 lbs

(5) GRADED GRAVEL AS BEDDING FOR RIPRAP

(6) GRADED GRAVEL - SAND TRANSITION ZONE

(7) 6" THICK STONE PITCHING OVER 6" GRADED GRAVEL AS BEDDING FOR PITCHING

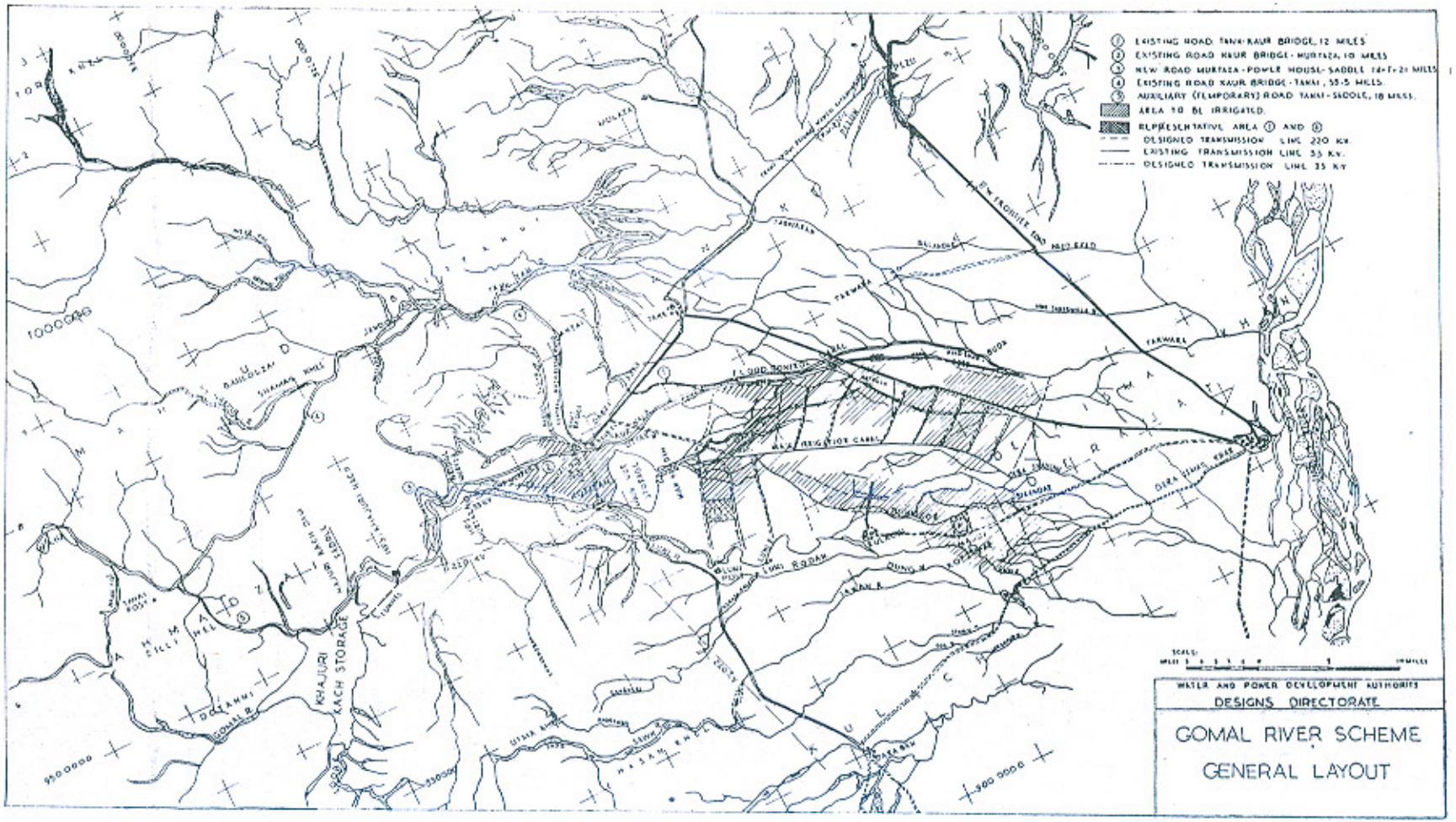
FILTER LEGEND:

(1) SAND FILTER

(2) FINE GRAVEL FILTER.

(3) COARSE GRAVEL FILTER

SECTION OF MAIN KHANPUR DAM


EXISTING ROAD TANK-KAUR BRIDGE, 12 MILES
EXISTING ROAD KAUR BRIDGE - MURTAZA, 10 MILES
NEW ROAD MURTAZA - POWLE HOUSE - SADDLE (4+7+2) MILES
EXISTING ROAD KAUR BRIDGE - TANAI, 55·5 MILES
AUXILIARY (TEMPORARY) ROAD TANAI - SADDLE, 18 MILES.
AREA TO BE IRRIGATED.
REPRESENTATIVE AREA ① AND ②
DESIGNED TRANSMISSION LINE 220 KV.
EXISTING TRANSMISSION LINE 33 KV.
DESIGNED TRANSMISSION LINE 33 KV
KHAJURI KACH STORAGE
WATER AND POWER DEVELOPMENT AUTHORITY
DESIGNS DIRECTORATE
GOMAL RIVER SCHEME
GENERAL LAYOUT

commodities in the Karachi area but also will meet the future requirements of Karachi and its surrounding area. It will also transform the parched barren land into a green belt around Karachi and will also help in improving its climate.

The project will have a gross commanded area of 1,31,000 acres of which it is proposed to irrigate 59,000 acres annually. Taking double cropping into consideration, the total area irrigated annually would be 84,000 acres.

The Ogee type 6,500 feet wide spillway with 4 Nos. deep Radial gates is located on the right bank away from the Main dam embankment and will have a maximum discharge capacity of 4,71,500 cusecs. The length of the diversion tunnel with 8 feet dia is 2,400 feet.

There are possibilities of cheap production of hydro-electric power from two 30 feet falls on the main canal.

According to latest estimates the project is to cost Rs. 130.0 million out of which Rs. 8 million will be in foreign exchange. This cost excludes the hydro-electric power generation proposals.

The expected life of the reservoir will be 65 years.

Gomal Zam Multipurpose Project

The Gomal Zam Multipurpose project is located in a narrow gorge 3 miles downstream of the confluence of the Gomal river, Zhob river and Wana Toi at Khajuri Kach (Adam Kok) in South Waziristan Agency.

This scheme was first conceived as mainly an irrigation project for the supply of water to the vast fertile but arid plain of Dera Ismail Khan district by harnessing the flood waters of the Gomal river and its tributaries. Being in the proximity of the Indus river, limited irrigation of some 50,000 acres was made possible by an inundation canal known as Paharpur canal. A sizable portion of the population of this district depends for its livelihood on flood irrigation which is uncertain and of limited utility.

It is a concrete gravity dam 500 feet high at Khajuri Kach in South Waziristan Agency. This dam will create a storage of 2.15 million acre feet. The Gomal river brings in huge quantities of sediments and therefore it is proposed to allocate roughly 1.15 million acre feet of storage for silt deposits. The ultimate usable storage is just over a million acre feet which is almost double the normal annual run-off in the river. This gives hundred per cent control over Gomal river waters and makes it a carry-over reservoir.

A spillway to cater for a maximum probable flood of 6,00,000 cusecs in-flowing into a full reservoir has been provided in the centre of the dam. Water will be led from this reservoir through a 3.92 miles long concrete lined tunnel to the Khajuri power-house where after generating about 90 m. V.A. electricity water will flow into Gomal river. After flowing for a distance of about 22 miles the water will be delivered into the Mian Noor reservoir through a diversion weir at Kot Azam. This reservoir will be created by the construction of a 67 feet high and 2780 feet long Mian Noor Dam. Two dykes, each nearly 10,000 feet long will be built on the left and right sides. The irrigation potential of the Gomal Dam Project will be 1,46.000 acres per year.

The total estimated cost of the Project is Rs. 383.6 million.

Utilization of Groundwater : Its Technique

By DR. NAZIR AHMAD

This is the third article of the series being issued in the Journal. Previously two articles on the same subject have already appeared. An article on Measuring Discharge of a Tubewell was printed in Volume XI, Nos. 1 *and* 2. All the *simple and scientific methods for recording discharge of a tubewell were discussed. Tables and formulas were put forth for evaluation of the yield. This article proved of immense use for all those who are now installing tubewells and want to determine their discharge accurately.*

Another article on Tubewell Pumping Machinery and their Trouble Shooting was printed in Volume XII, No. 1, *March,* 1967. *It dealt with the various aspects of Pumping Machinery, and gave information with regard to common troubles which can be set right.*

In the present article we have discussed the methods generally used to utilize the groundwater. Brief information with regard to open well, cavity well and tubewell is given. Detail is given about the tubewell strainers, causes for their deterioration and some remedies. The fourth article which is planned will deal with the Hydraulics of Tubewells.

Land and Water : two bounties of God

Water and land constitute the sources of life. God has showered both these bounties for the people of West Pakistan. He has given perennial rivers and a vast tract of fertile culturable land, the biggest compact unit, nowhere else found in the world. The formation of the Indus Plains contains the largest reservoir of fresh water. Dig wherever you like, you will find water. This gift of God had remained unutilized till recently. At times it was considered a menace causing waterlogging to the land but it was in fact one of the most bounteous gifts of God in disguise. For hundreds of years it has been used very sparingly. It is only now with the development of mechanical methods of utilization that this natural resource has been rediscovered.

The methods of utilization of Groundwater

The methods adopted to utilize the groundwater are:—

1. Open wells.
2. Open wells provided with one or

more strainers at its bed.

3. Cavity wells, and
4. Tubewells.

Open well

The art of constructing a paved open well is as old as the civilization of this country. It was known to the people of this country much earlier than the Mohenjo-Daro civilization. A Persian-wheel to lift water seems to have appeared along with an open paved well. The well was very often 10 ft. in diameter having about 75 sq. ft. of percolating sandy bed. The brick walls of the well were made without the use of mortar to act as a medium for side percolation. The yield of such a well, when the water level was depressed by 2 or 4 ft., remained up to 0.1 to 0.2 cusec of water. Higher yields were not possible as sand started slipping into the well when the depression was increased beyond five feet.

Open well provided with a strainer

When railways were introduced in this country, a large volume of good quality water was needed at many places. Open wells were considered a ready means of procuring water, but unfortunately the yield could not be increased due to the slipping of sand. It often resulted in the failure of the well. The Railway Engineers thought of using one and sometimes more strainers recently developed by Brownlie, Legget, Thompson etc., in the bed of an open well to increase the percolating area and consequently the discharge of the well. The length of the strainers used varied from 50 to 100 ft. (Fig. 1). Pumping by this system increased the yield of the well, sometimes to nearly double the original order, but the limit of the depression head causing slipping of sand remained unaffected.

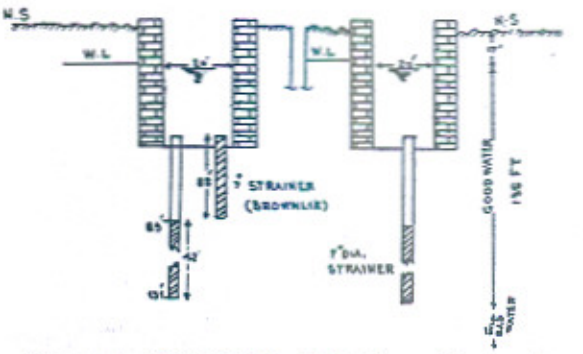


Figure 1. Open wells at Rahimyarkhan and Jacobabad provided with one or more strainers to increase their discharge.

Attempts were made to add shingles and stones in the bed of the open well to weigh the sand and thus to increase the depression head (Fig. 2). The density of stones under

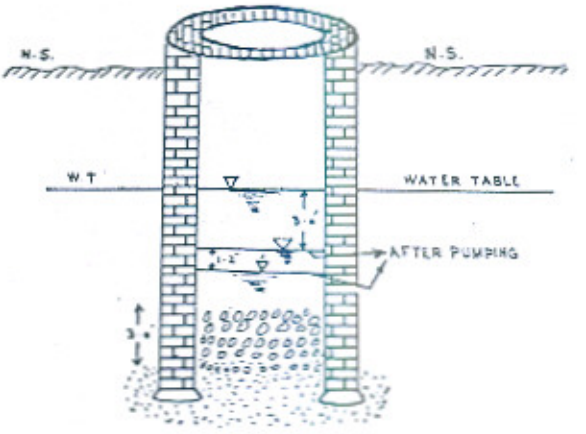


Figure 2. Open well with Shingles at its bed.

water being 1.4 times that of water, addition of one foot thick stones, resulted in an increase of the depression head by 0.4 ft. This was, however, a costly method. It could be used where shingles were cheap. Some sand also moved through the shingle bed. At that time the conception of adding a suitable type of graded filter to check the flow of sand was not fully known. Installation of a proper type of filter could have resulted in the increase of depression of water level in the well with subsequent increase in yield of water. The limited size of the percolat-

ing area was the other drawback. This method thus did not become very popular although at some sites engineers have still continued to use it. The technique of adding strainers in open well is still practised in the foothill district of Sialkot where 'clabas' (clay strainer, Fig. 3) are installed in the bed of open wells to increase their outputs.

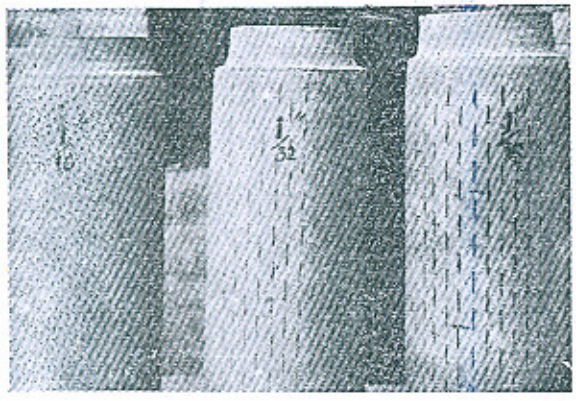


Figure 3. Baked clay strainer (Calaba) generally used in the bed of open well.

Cavity well

In the Indus formation there are places where clay layer of sufficient thickness exist below the natural surface. If such a layer is 20 to 50 ft. thick followed by water bearing sand then boring through the clay, a cavity is created in the sand, by surging and pumping. The size of the cavity can be made bigger than the bed of an open well. Installing a blind iron pipe through the clay bed pumping is possible with high depression head (Fig. 4). This technique is cheaper than an open well. It is possible to increase the depression head. The yield is often more than an open well. This method is, however, possible only at a few suitable sites and is not very popular due to the factors of uncertainty.

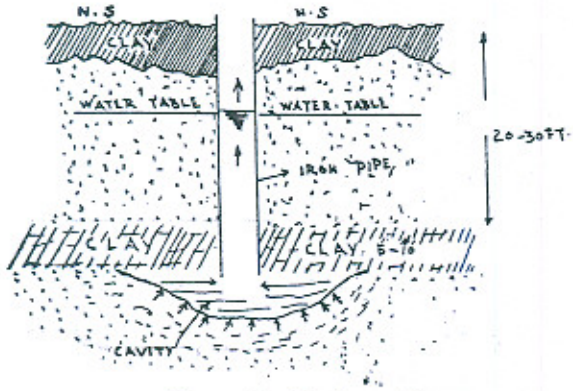


Figure 4. Cavity well.

Tubewell

Tubewell technique was developed at the close of the last century. It followed the development of a centrifugal pumping set and a strainer to yield water.

The Public Health Engineers were the first to start using this device and replaced their old system of percolating gallaries and pumping water by means of steam engine. Great interest in the use of this system developed when Legget and Thomas in Amritsar Workshop, Brownlie in Agricultural College, Lyallpur, successfully developed improved types of tubewell strainers.

The Irrigation Engineers who had also been experimenting on tubewells for Irrigation, planned their first project in 1938 near the Shalimar Gardens. It was a project of 20 tubewells and was named as Karol Tubewell Scheme. Another Project, the Rasul Tubewell Scheme was undertaken in 1945. Now at this stage tubewells are considered to be an important, rather the only means to exploit the groundwater as well as for drainage of the land. The Government is undertaking several tubewell projects. Scarp No. 1 in Central Rechna is completed. Scarp No. 2 in Chej Doab and Sukkur Khairpur tubewells scheme are almost complete. Scarps No. 3, 4 and 5 have passed the feasibility stages.

Another factor which has come into

prominence is the private interest in the installation of wells. A cheap design has been developed. It has lowered the cost of the installation and brought it within the means of an average farmer. Its low cost, use of indigenous material, yield of 25 to 30 times more water than a Persian-wheel, mechanical operation and elimination of the bullocks labour, are a few attractions. The tubewells being installed by farmers now, in 1950-67, are even cheaper than the cost of Government installed tubewell in 1920. It is cheaper than constructing and operating a Persian-wheel.

Installation of a Tubewell in different areas of West Pakistan

The areas of West Pakistan for installing tubewells can be divided into four groups.

1. Active and meander flood plains close to rivers having persistent recharge of fresh water.
2. Areas adjacent to flood plains, containing good quality groundwater in considerable depths.
3. Deep saline water zones with good quality water at top.
4. Zones of saline groundwater throughout the depth.

On both sides of the rivers, in a strip of a few miles' width, there occurs annual river spills recharging the formation. The groundwater is of very good quality and can be directly used on the land. These areas have flood hazard and are generally without irrigation canals or non-perrenial canals. The groundwater level remains high within 10 to 20 ft. from surface and fluctuates between 3 to 5 ft. with the rise and fall of the rivers. Pumping cannot appreciably affect the groundwater levels except in the regions of Sutlej and Ravi rivers which will ultimately be diverted by India and their flood plains will not get the annual recharge except through some minor Nullahs. These areas in future will have serious deficiency in recharge.

Adjacent to flood plains exist extensive lands spread in the four Doabs of the Punjab. Here under 77 per cent of the land, exists groundwater of very low salt contents generally below 1000 ppm. This good quality water exists in considerable depths so that when pumped out can be used either directly on the land or mixed with the canal water when the quality is unsatisfactory. About 23 percent of 16 million acres of land in the four Doabs of the Punjab lie on groundwater which is saline. Fortunately in these areas, the top 50 to 100 ft. depth, again possesses good quality water. It is possible by the use of partial penetrating tubewells having multistrainers to pump sufficient quantity of good quality water. This technique can be used extensively in Sind, in the Sukkur Barrage region where at many places small stretches of shallow good quality water are available. Although such areas in Sind are not yet marked but there are places which were old river creeks or areas adjacent to canals where good quality groundwater is available.

The last group of land is such which possess unsuitable groundwater right from the top downwards. Extensive land of this type exists in Ghulam Mohammad Barrage region and in the lower zones of the Sukkur Barrage. Here tubewells for water supply or for drainage will not be suitable and lasting. Other drainage measures like tile drains open drains shall have to be provided. It is possible that after some time the quality of


U.S.S.R
AFGHANISTAN
HIMALAYAN MOUNTAINS
KARAKUNA
HUNZA R.
GILGIT
INDUS R.
KABUL R.
SWAT R.
JHELUM R.
JAMMU AND KASHMIR
RAWALPINDI
KALABAGH
JOAN R.
MANGLA
SALT RANGE
MADHOPUR
CHENAB
LAHORE
FEROZPUR
INDUS
JHANG
SHAHIWAL
MULTAN
SUTLEJ
QUETTA
PANJNAD
SUKKUR
GUDU
HYDERABAD
KARACHI
ARABIAN SEA
FIG:
WEST PAKISTAN
GROUND WATER SALINITY
SALINE G/W DEEPER THAN 50 TO 90 FT.
INTERMEDIATE ZONE WITH SALINE WATER BEYOND 50 TO 90 FT.
GOOD QUALITY WATER IN DEPTH MORE THAN 500 FT.
HIGHLY SALINE (MORE THAN 5000 PPM) FROM SHALLOW DEPTHS
CONCENTRATION MORE THAN 5000 PPM.
CONCENTRATION BET: 1000→5000 PPM.
CONCENTRATION LESS THAN 1000 PPM.
INTERNATIONAL BOUNDR
FIG: 5

the effluent may improve sufficient to be mixed with fresh canal water. Fig. 5 gives approximaterly the extent of the four zones as discussed above.

Farmers criterion for siting a tubewell

When a farmer is to instal a tubewell on his land, he has to decide about its siting. He would like to locate it at a place which will have a good command of his land. A high elevated site might be suitable. This may cost some extra money for the construction of the pump-house as a centrifugal pump has to be installed as close to the groundwater level as possible. Long water courses result in wastage of water both by seepage and by other causes. A central place suitable for distributing water by short length water courses may, however, be preferable. The siting of a tubewell will also be decided by the farmer from the consideration of approach and his own accommodation etc. These are the considerations relating to the convenience of the farmer. There are a few other considerations which have to be kept in view while siting a tubewell. These relate to the nature of formation and the quality of groundwater.

Siting on the basis of high water-yielding formation

The formation of the Indus Plains varies within short distances and from place to place. That formation is suitable which has the greatest depth of water yielding sand. It may happen that a site selected for a tubewell installation has a thick clay layer. Shifting the site by a few hundred feet may avoid the presence of the thick clay layers. There are now many tubewells spread all over the Punjab and Bahawalpur plains. A preliminary information about the strata formation of a site can be collected by reference to those. Similarly Wasid has also carried out extensive drilling in the country. Information about the site can be had from the records of that department.

Collection of information for a new site

If a site is new, for which no information is available, then it will be preferable to carry out an exploratory bore with 4 to 6 inches diameter pipe. A big size bore, although suitable and which can, later on, be used for installing a tubewell, will be costly; while boring the formation samples at every 10 ft. depth or at every change of strata may be collected in metallic, wooden or plastic containers. A preliminary classification of the grades of sand, silt and clay can be carried out visually. The sand may further be classified into fine, medium fine and medium coarse grades. The position of occurrence of clay layers, silt or dirty fine sand may carefully be recorded in a note book. A sieve analysis of sand will be preferable. This is done by standard sieves usually available in laboratories. A simpler and approximate method is to purchase 100 mesh sieve with square holes. It can be used to classify a dry specimen of sand formation. Different grades of sand particles have different order of retension on the sieves. A number of samples were sieved through a 100 mesh sieve and the percentage of various grades of sand particles retained on this sieve was plotted against percentage retention. It is plotted in fig. 6. If the retention is 10 to 35 percent, the sand is very fine. Fifty to seventy percent retention is for fine grade and 80 to 100 percent retention is for fine grade of medium sand.

Coarse grade of medium sand cannot be classified by this size of the sieve. We have mentioned 100 mesh sieve as it is commonly

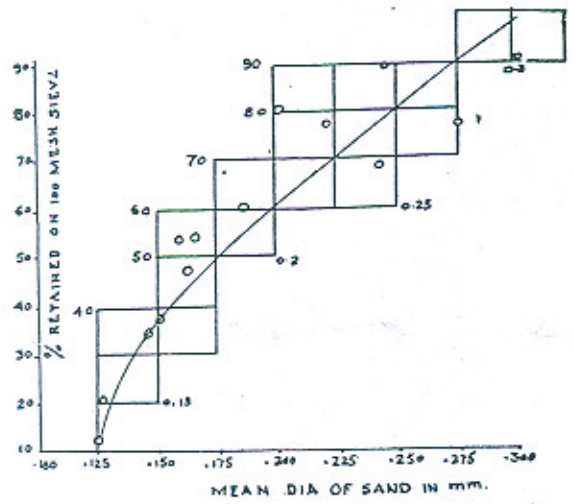


Figure 6. Percentage of sand of various mean dia. retained on 100 mesh sieve.

available in the country.

If somehow a sieve of 50 mesh is available, then the classification of all grades of sand can be made. Percentage of sand of different grades retained on this sieve is plotted in fig. 7 and also given in table 1a.

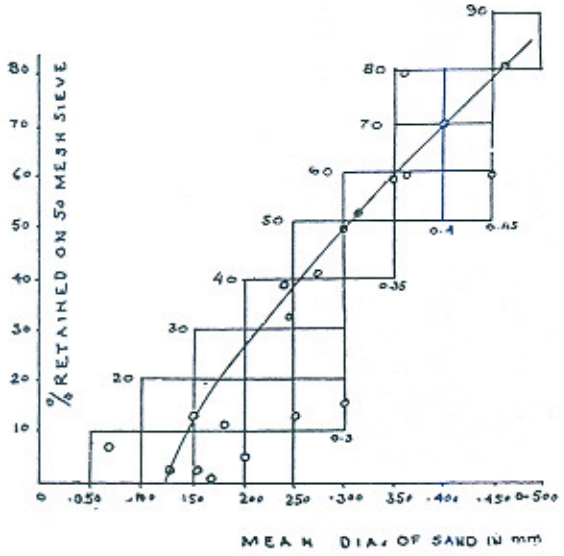


Figure 7. Percentage of Sand of various dia. retained on 50 mesh sieve

Very satisfactory results can be attained by using both these sieves.

Procurement of a 100 mesh sieve is easy. It is available everywhere. Arrangement for a 50 mesh sieve can help an average person to classify sands fairly accurately. Every driller ought to posses both these sieves and the chart shown in Table 1a.

TABLE 1a

Classification of sand by square hole sieves of 100 *and* 50 *mesh.*

Mean dia of. sand m.m.	Classification Int. Standard	%retained on 100 mesh	%retained on 50 mesh
0.125	Very fine sand	10	7
0.15	Very fine sand	40	10
0.175	Fine sand	50	20
0.20	Fine sand	60	30
0.25	Med. fine sand	80	40
0.30	Med. fine sand	100	50
0.35	Med. C. Sand	..	60
0.40	Med. C. Sand	..	70

Recording of groundwater levels

The recording of real groundwater level is important. Sometimes perched watertable exists as shown in Fig. 8. It is not the

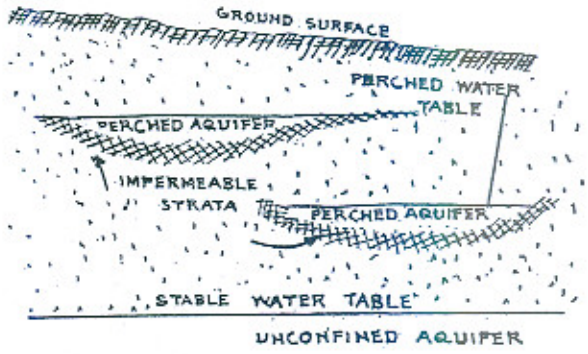


Figure 8. Examples of Perched water table.

actual level of the groundwater. This water is temporary and cannot yield water over a long time. Recording of groundwater level and its fluctuations help in the selection of the pumping machinery and its installation at a proper depth.

The recording of changes of groundwater

levels during monsoon or dry periods is important for selecting the location of the pumping set.

Avoid pockets of saline groundwater

A general information about the quality of groundwater is available for the whole of the Northern areas. There are, however, certain areas with pockets of saline water. These are in general not extensive and can sometimes be avoided by shifting the site a few hundred feet. In case a saline water pocket cannot be avoided, its direct withdrawal can be avoided by cutting it off by a blind pipe. This is very successfully done if the pocket is enclosed between two clay layers.

Determination of Salt Content of Groundwater; Use of a Conductivity Meter

A quick and accurate method to determine the total salts in a specimen of water, is by determining its electrical conductivity. All natural waters have some soluble salts, so these are electrically conductive. Their conductivity which is inverse of electrical resistance increases with increase of salt content. Different salts such as chlorides, carbonates, sulphates, nitrates etc., have different orders of conductance at the same temperature. The variation is very minor, so that measurement of conductivity is taken as a measure of total soluble salts.

The conductivity is an inverse of resistance. It is expressed as Moh in contrast to to ohm which is a unit of resistance. Just as specific resistance is measured per unit volume, similarly Moh is also measured in unit volume but generally expressed as Moh per cm. The value of conductivity is usually low, so that it is expressed either as milli-moh or micro moh. per cm. The later unit is very common and we are accustomed to express the conductivity as 500,1000 or 5000 etc. m.m/cm. (micro-moh per cm). When using the unit as milli-moh the observed value of 5000 micro moh/cm is expressed as 5.0 milli m/cm.

It has also been found out that the conductivity can be used to determine the actual salt content in term of part per million (ppm) or percentage.

Experimentally it is observed that conductivity when multiplied by a factor 0.64. Fig. 9 gives the salts in ppm. For example

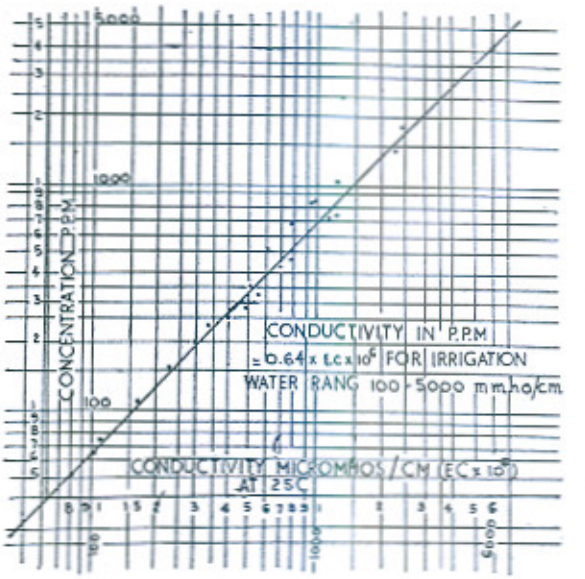


Fig. 9

a conductivity measurement of 1000 micro-m./cm will have salts equal to 640 ppm.

Temperature effect on the measurement of Conductance

It is known that resistance of materials vary with change in temperature. The variation is expressed as

$$R_t = R_o(1 + \alpha t + \beta t^2 + \ldots)$$

Usually the factors βt^2 and of higher order are too insignificant and are neglected, so that the resistance changes directly as the

change in temperature is a constant for a given material. The variation of conductance with change in temperature of water is shown in Fig. 10 for waters of four salt contents.

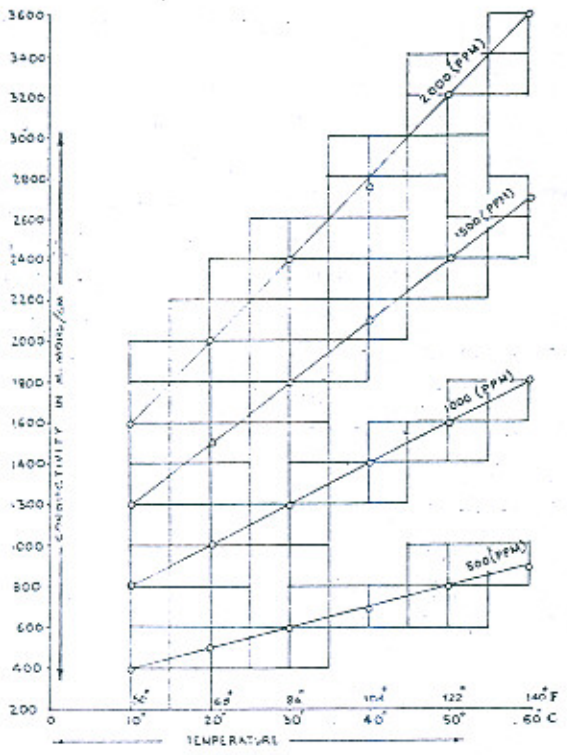


Figure 10. Variation of conductivity with temperature.

The relation of conductivity and change of temperature is linear. If conductivity is measured at any temperature t, it can be converted to that for 20°C by the use of the relation:

$$C_t = C_{20}(0.6+0.02t)$$

or $C_{20} = C_t/(0.6+0.02t)$ where t is the temperature in °C above or below 20°C.

The total souble salts in term of ppm., are determined from the value of C_{20} by multiplying it with a factor 0.64. These can also be determined directly without conversion of conductance to 20°C. If conductance is known for t°C, then total solids for a temperature of 20°C are obtained from a relation of the type.

$$\text{Total solids in ppm, at } 20°C = \frac{Ct}{0.90+0.03t}$$

The salts percentage is determined as under:

$$\text{Percentage soluble salts at } 20°C = \frac{Ct}{9000+300t}$$

Laboratory estimation of soluble salts

In a laboratory two methods are generally used, one is a direct method by which a known specimen of water is taken and it is oven-dried. The salts are left in the dish which are weighed and their percentage or ppm. value is determined on the basis of the quantity of water sample taken and got evaporated.

The second method which is very quick is the use of conductivity meter. The instrument is shown in Fig. 11. It consists of a

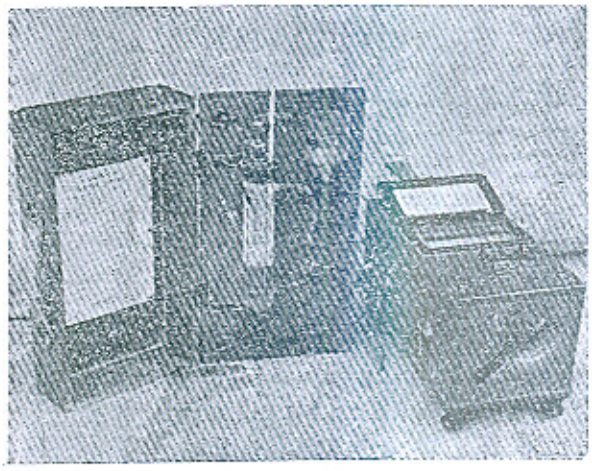


Figure 11

megger which has an alternating current generator and a galvanometer measuring the conductivity. The solution of which the conductance is to be determined is poured in a glass tube which has another tube inside. This tube has two electrodes, one at the bottom which is fixed and another at top which is variable and can be moved up and down. The diameter of the tube is generally one cm., and the second electrode is kept

at a distance of about 10 cm., from the fixed electrodes. In this instrument the conductance is measured directly for 20°C. The effect of temperature is eliminated by adjusting the position of the top electrode corresponding to the temperature of the specimen.

A simple apparatus to determine approximately the salts content of water

A conductivity meter bridge is not available commonly. It is also costly and not very hardly. An apparatus can be devised which can give the conductance although the value so determined will be approximate. The

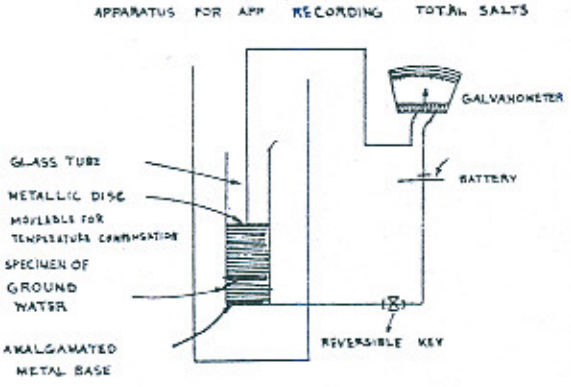


Figure 11-A.

apparatus consists of a Western type galvanometer measuring micro ampere, a battery cell, a resistance and a glass tube having two electrodes, one fixed and the other movable.

These are fixed to a glass or a plastic tube. The movable electrodes have calibration showing the temperature scale. This electrode is moved up or down according to the temperature of the water of which the salt content is to be determined.

In this instrument we use direct current which produces polarisation on the electrodes if the current is passed for a long time. Thus the first precaution is to pass the current for as short a period as possible. It will be useful if current is sometime reversed.

Another useful precaution is to have a standard solution and check the galvanometer reading with reference to that standard solution. This apparatus is shown in Fig. 11-A.

What is a strainer or a screen

A strainer is an important component of a tubewell. Its function is to hold back the formation and allow sand free water to flow into it, when the water level is lowered inside it. For water to flow freely without obstruction or resistance, a strainer should have slits or holes cut on its body. The area of these slits or holes should correspond to the yield of the formation. Sometimes this much open area cannot be attained keeping in view the strength of the strainer. It is, thus difficult to avoid a loss of head which occurs at the change of medium. It can, however, be minimised.

Development of a strainer

A simple strainer is formed by drilling fine holes in an iron pipe. This type was however not practicable as the size of sand formation occurring particularly in the Indus plains is very small. The medium sand which predominates has the biggest individual particles, smaller than 0.5 mm. The mean size of coarse type of medium sand is 0.35 mm., and fine type of medium sand is 0.25 mm. A fine grade of sand which is also water-yielding has a mean size of 0.2 mm. Thus it was fairly difficult to prepare a strainer with holes as fine as the medium grades of sand occurring in the Indus plains. In case of an iron pipe the rusting blocked the holes in a short time.

At the close of the 19th century, a type of strainer was developed which consisted of a galvanised iron pipe on which 5 mm.

diameter holes were drilled at such distance apart as not to impair its strength. The holes were covered by wrapping a brass or copper wire gauze. One hundred mesh wire gauze gives the size of the square holes equal to about 0.15 mm. This fine sieve was further protected by a stout brass sheet of 20 to 22 gauze in which 3 to 5 mm., holes were punched. This type of strainer is still in use for small discharge hand pumps.

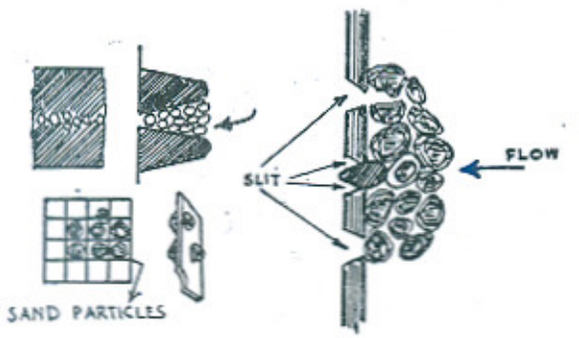


Figure. 12. Blocking of round or rectangular holes with formation particles.

This strainer has two defects. The particles of sand formation are generally angular. There gets fixed up in the square holes of the screen as shown in Fig. 12 leaving a small space for the water to percolate. The second serious defect is that the inner iron pipe gets rusted which moves out of the fine wire gauze and cement the sand particles thus blocking the water passage. This type of strainer was found unsuitable for large water supply arrangements.

Development of a slit type strainer

Between 1905 to 1915 many attempts were made to produce a strainer free from the defects of an iron pipe strainer. Several engineers in Amritsar Irrigation Workshop and in the Engineering section of Agriculture College, like Brownlie, Thompson, Leggets, Ashford, etc. experimented with various designs of strainers.

A design of convoluted iron pipe was

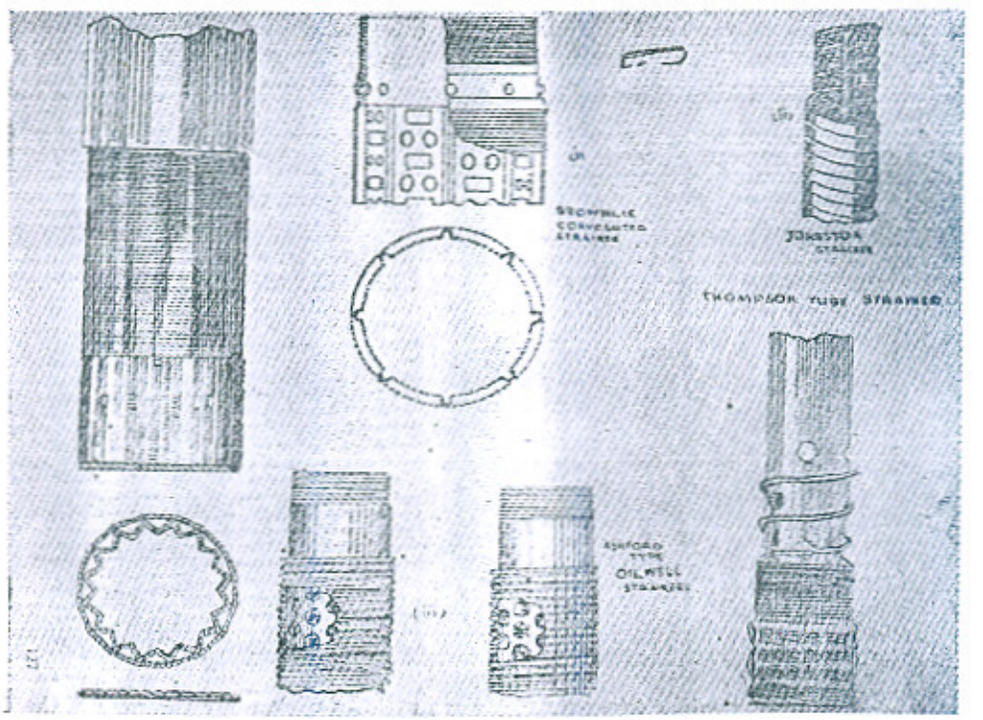


Figure 13. Specimens of convoluted and wire wound strainers of early period.

perfected. It had holes and an envelope of brass wire gauze to have a minimum contact with the iron pipe. This type of strainer is shown in Fig. 13 In another type a cadium plated iron pipe was used. A strainer was developed by winding a brass wire, flat at one edge. This is shown in the same figure No. 13. This was an earlier attempt to construct a wire wound strainer.

Further experiments led to the development of brass or copper sheet strainers in which long slits either horizontally or vertically were cut. This strainer became very popular and was extensively used.

Shape of the slits in a brass strainer

In the beginning slits were cut on the surface of a brass pipe. The cutting tools made a V-shaped cut on the surface. It was soon realised that the V-cut was a prospective place for the sand particles to accumulate and block the slits as shown in Fig. 12. Although this blocking was not as much as for a square hole but it still reduced the open area. Very soon the construction of a brass slit strainer was improved. A brass sheet was selected and slits were cut in it. It was then rolled into the shape of a pipe and welded. The V-cut were kept inside and the outer surface represented rectangular sharp edge slits. This eliminated the chance for the deposition of the sand particles and if any particle passed through the slit, the wide V-shape helped it to move away by the passage of water. This type of strainer is showns in Figs. 14 and 15. It has been used extensively in the tubewell projects undertaken by the Irrigation and Public Health Departments. Before independence it was patented under the name of Tej strainer.

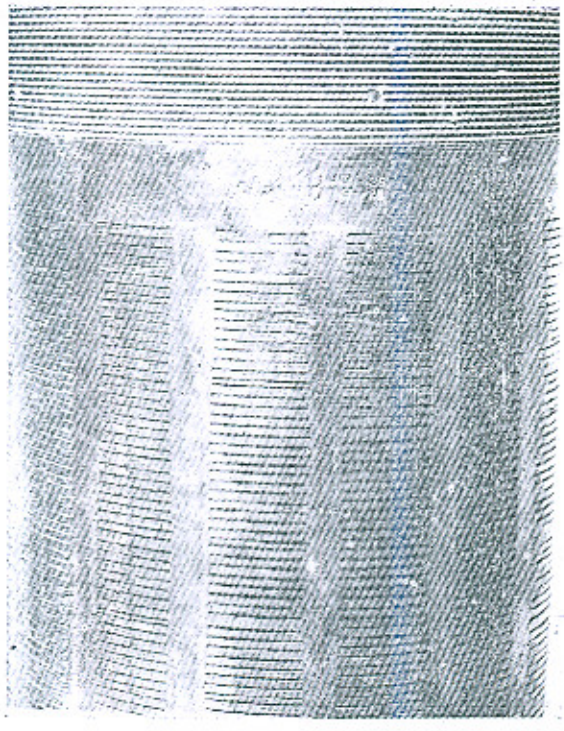


Figure 14. A slit type brass strainer very commonly used in Pakistan. Before independence it was called Tej Strainer.

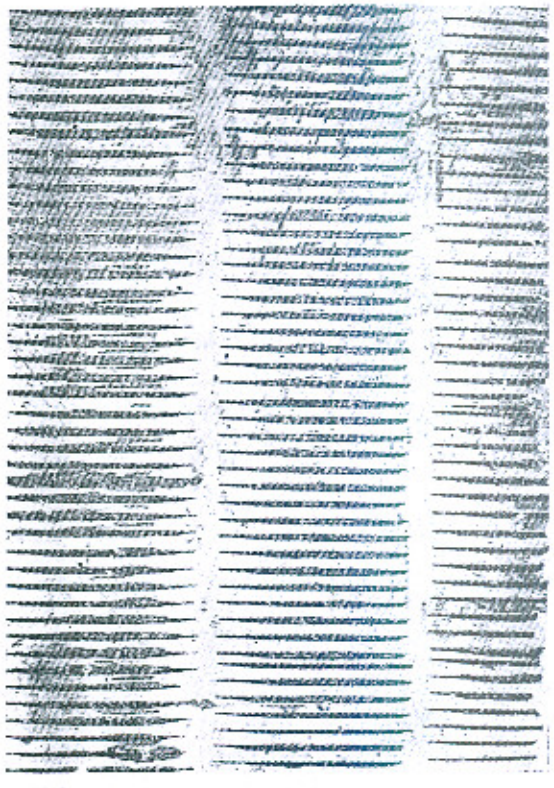


Figure 15. A brass strainer has sharp slits on the outside and V-shape as shown in this figure on the inside.

The idea of wire wound strainer was again revived, so that instead of iron, a brass pipe was used and on the surface of which inclined cuts four to five inches long and one to one and a half inch wide were cut and its surface was threaded with groove type cuts. A brass wire with one surface flattened was wound in the threads and welded at selected points. This strainer was patented under the name of Sarup Bansi. A specimen of the same is shown in Fig. 16. It was used

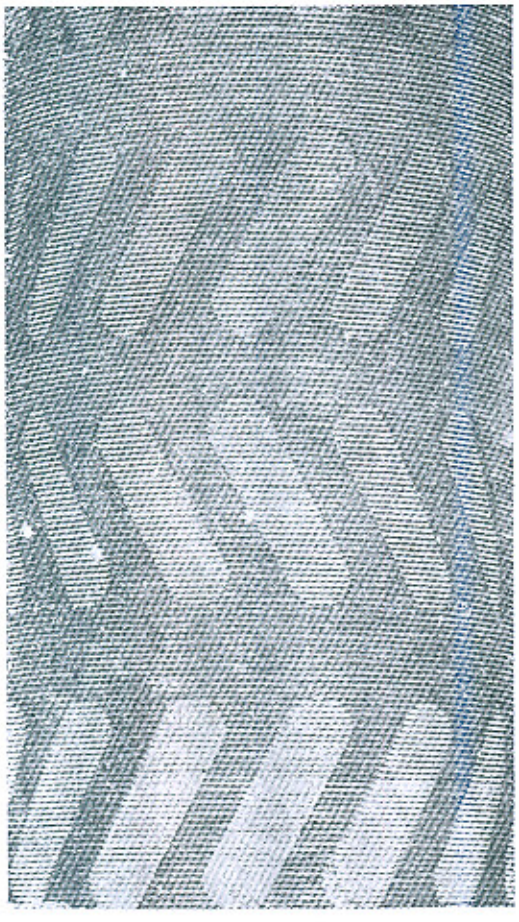


Figure 16. A specimen of wire wound brass strainer, sometimes called Sarup Bansi Strainer not used very commonly.

in many tubewells but it did not become as popular as the slit type strainer.

Open area of slit type strainer and permissible size of slits

We have put forth that the fines and formation occurring in the Indus plains yields about 25 percent water. This water is held in about 40 percent pores of the formation.

Open area on a slit type strainer is based upon the size of the slits and their number. The size of slits is limited by the size of formation which is to be kept in position by the screening action of the strainer. Any one type of formation contains different sizes of particles, although in the Indus plains the type of particles of one grade predominates and the uniformity coefficient as defined previously lies between 2 to 3. The average mean size of particles lies between 0.2 to 0.35 mm., as shown in table 1. It may be noted that the widest slit cannot be more than 0.35 mm.

In consideration to the strength of the strainer, the slits cannot be closer than 3 to 5 mm. On account of these limitations the open area of a strainer could not be increased more than 4 to 5 percent.

The engineers of the country soon realised that wet sand under certain conditions of pressure formed a type of an arch called a bridge made up of big and small size particles

These big particles held the small size particles to flow with water through the slit of the strainer. A typical bridge formation is shown in Fig. 17. The flowing water loads the arch of sand particles which remain in position. On account of this property it was found that the size of the slits could be widened to the extent to retain only 15 to 20 percent of the sand particles. The bridge did not allow the rest of the 80 percent finer particles to pass through. Under this property the size of the slits could be increased to some extent as shown in table 1.

TABLE No. 1

Sand classification	Mean diameter, D_{50}, in mm.	Size of slits corresponding to 50% of the sand retained, inches	Size of slits corresponding to 15 or 20% sand retained, inches
Coarse grade of medium sand	0.35	14/1000	18/1000
Fine grade of medium sand	0.3	12/1000	14/1000
"	0.25	10/1000	12/1000
Fine sand	0.2	8/1000	12/1000
Very fine sand	0.18	6/1000	10/1000
"	0.16	4/1000	8/1000

This caused a slight increase in the open area which still remained close to 5 percent.

Prior to 1930 the technique of boring with big size casing pipe was not fully known nor the importance and the advantages of shrouding the strainer were known. In those days tubewells were installed by boring with small diameter pipe and were kept unshrouded. Under this condition, the use of strainer having the size of slits sufficient to retain 20 percent of the formation was a real advantage. This phenomena of formation of a bridge was somehow known to the Public Health Engineers, so that up till 1930 all tubewells installed by the famous Public Health Engineer, Mr. Howell had slit type strainer, unshrouded and with the size of

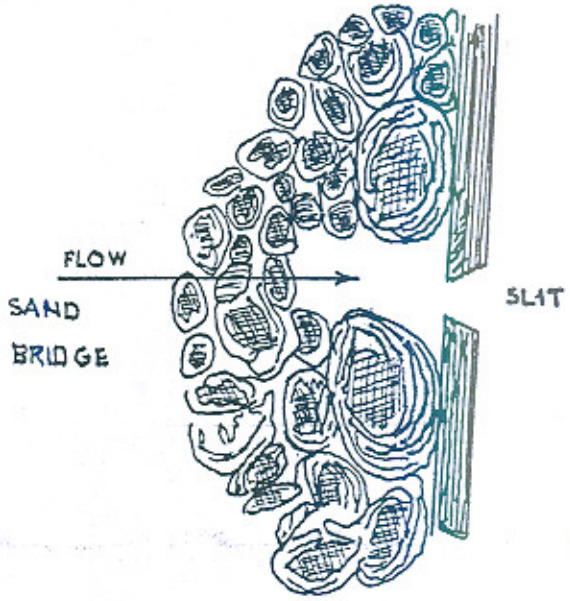


Figure 17. Bridging of Sand in front of a Slit.

slits such as to retain only 20 percent of the formation.

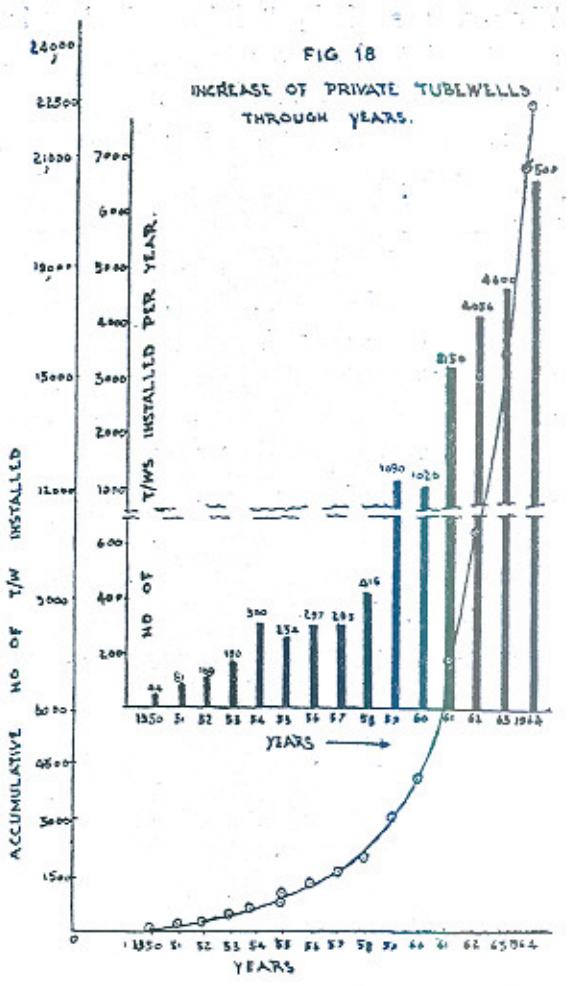
String type strainer

It has been a practice in this country to use Munj string for binding of baked clay buckets of a Persian-wheel. This string was found to last in water for a longer period as compared to strings of other materials.

When development of various types of strainer was taking place, some thought was given to the construction of a munj wound string strainer. It was, however, found out that the material deteriorated and developed unpleasant smell. Further experiment showed that a string of coconut called the coir string was much more lasting in water and did not deteriorate nor developed any smell.

When the Irrigation Department undertook its first project of Karol tubewell, coir string strainer was known to exist but it had no background of experience.

Its use, however, remained limited only to a few private persons who used coir strainer in their hand pumps. By 1950 some farmers had actually got installed a few tubewells with strainers of this material. Slowly confidence was built up. Farmer saw the advantages of pumping water from a tubewell. It gave a good return. Farmers of Sialkot and Gujranwala used this excess water for growing rice. It was soon realised that the total cost of the tubewell could be recovered within a few years. From 1950 onward the interest of the farmers to instal tubewells with this type of strainer started to increase. This speed of installation of tubewells is now increasing at a phenomenal rate. The rising curve of installation is shown in Fig. 18. Mainly from their own resources, the people are installing coir string strainer tubewells. In fact the present



interest of the people in the solution of the problems of waterlogging is a direct result of the development of coir string strainer and confidence in its use.

The Agriculture Department has installed the largest number of tubewells with coir string strainer. The private drillers also use the same strainer. Recently Irrigation Department has also started to use it. It has not yet been used in any of the foreign added or designed tubewell projects.

A coir string strainer has innumerable advantages, over the slit type strainer. The first advantage is with regard to the open area. Only a string type strainer can have the largest proportion of the open area.

The screens made by E. Johnson in America are found to have the largest open area. These strainers are wire wound.

The open area of a coir string strainer has not been accurately determined. The few experiments conducted show that it may be of the order of 15 percent. A coir string is fibrous and porous. When two strings are wound close together, allowing no space between the string, but due to the twisting of the string open spaces are left, which are of the order of 1/32 to 1/64 of an inch and even smaller. Water flows through these. It also flows through the body of the string. Thus the whole body of the coir string acts as a screen. The pores are fairly small and yet the open space is considerable. For this reason it is used facing the coarse or fine sand and may even face the clay layers. It can thus replace the costly blind pipe installed to face the clay formation occurring deep in the formation.

Unfortunately no standard has ever been laid for this type of strainer. These are now being constructed by everybody and everywhere. No precautions are taken in its preparation and no standard exists for its materials of construction. We will, however, discuss some aspects of the construction of this type of strainer.

Cage on which the strings are wound

Coir string strainer is constructed on a frame or a cage which is made of iron strips riverted or welded to iron flanges. The size of the strainer in use vary from 4 inches to 10 inches in diameter. A common practice is to use 6 inches diameter strainer. Flanges are 6 inches long, with 2 inches depth of 10 number threads per inch. The thickness of mild steel plate used in the preparation of the flanges is 2/8 inches. Although some manufacturers use a still thinner plate. The strainers length is 8 to 10 ft. which includes the flanges to which are fixed the iron strips. These are 3/16 inches thick and one inch wide and are spaced one to 1½ inches apart. In order to avoid bulking, stiffners at a distance of 6 to 9 inches apart are provided. To lower the cost, the local manufacturers use thin iron strips, sometimes thinner than 1/8 inch.

Another alternative for the construction of a cage is to use iron bars welded to the flanges. A specimen is shown in Fig. 19.

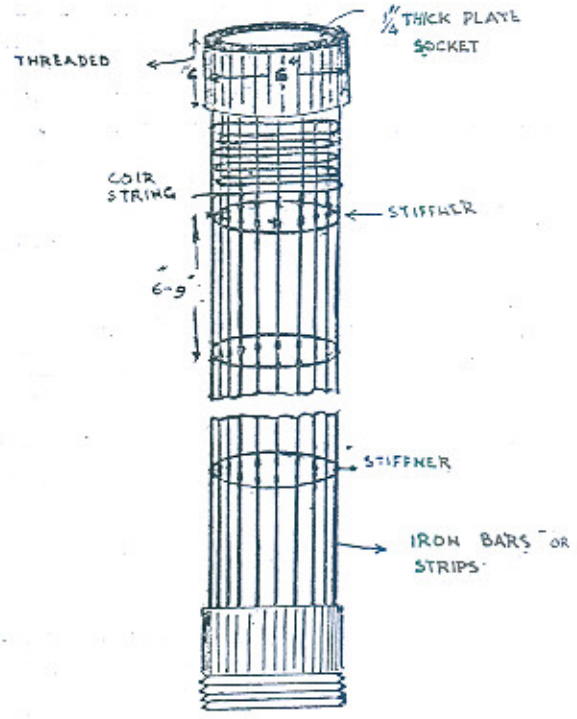


Figure 19. 9" dia. iron cage for coir string strainer

These bars can be 2/8 inch thick. In a six inches diameter strainer, 12 bars. 1½ inches apart can be used. If the diameter of the strainer is 10 inches, the number of bars increases to 20. These also need stiffners at the same distance apart.

Protection against rusting

All iron pieces must get rusted sooner or later. It has been noticed that rust affects the strength of coir string. The strength of the coir string adjoining the iron strip was checked. It was found to be weaker than the rest of the string. Protection of the iron cage against rusting is thus very essential. The cheapest material which can protect iron is a coating with bitumen, 30-40 grades, heated to about 400°F and is applied at a high temperature to cover the iron components. Ordinary sarkanda weeds brush can be used for painting. Thickness of bitumen coating of about 1/16 inch is sufficient. If facilities exist, bitumen can be kept melted in a tank and the cage can be dipped in the hot stuff. Sometimes lime is also mixed with bitumen. Its superiority is still unknown. It may be noted that the painting of the cage with oily emulsion such as Black Japan or other such materials is not lasting. Epoxy Resin may give the best protection but it is not produced in the country and is costly as well. For the period a coir string strainer is to last, the use of bitumen coating is satisfactory.

Use of bamboo or wood

While preparing a cage, it is possible to replace the iron bars by bamboo or wooden strips (fig. 20). These can be used in areas where both these materials are cheap and only that specimen is used which lasts for a number of years in water. Bulking and warping of bamboo or wooden strips is to be given special consideration as this will loosen the coir string. In West Pakistan the use of iron is, however, cheaper.

Coir string

Coir string is made of coconut fibres. It

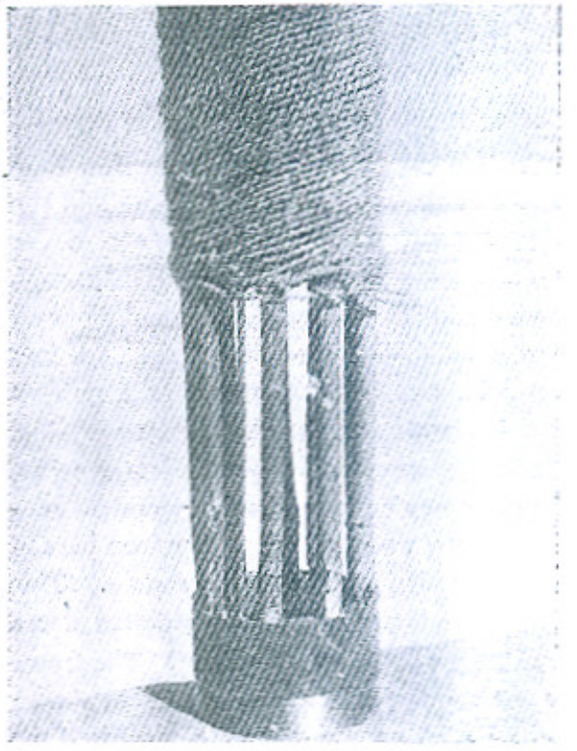


Figure 20. A cage made of bamboo for winding coir string.

is produced in East Pakistan. It is also imported from Ceylon and other countries. Its fibres are usually 1/2 to 2 mm. thick. The coir string is imported in various thicknesses and is wound to different stiffnesses. A suitable size of the string for use in strainers is 3/16 inch. Its tolerance of thickness should be 1/4 to 1/8 inch. The breaking strength of this size of the string is 50 to 70 Lbs. On wetting a coir string does not shrink. If it is wound under tension, on wetting it will expand eliminating slightly the tension. It is unlike other fibrous materials which generally shrink on wetting. This special property makes it more suitable for the construction of the strainers. This material is very durable as it does not rot in water. Salts have minor effect on its strength, Its breaking strength after long immersion

in moderately saline water decreases by about 20 to 30%.

Winding of coir string

Winding of a coir string on an iron cage may be done with due care. If knots in the string are left on the outer surface of the windings, these create big holes through which sand can flow. The winding may start on an iron flat or bar of the cage and after winding about 4 inches in length, it may be continued from the flange side. Winding is done under a uniform tension. The cage may be balanced on wooden supports. Two wooden pieces with iron bars in their centre are fixed in the iron cage. This is then supported on the two wooden pieces in which grooves have been out. The frame will be supported on these pieces as shown in Fig. 21. A person rotates the cage and the string continues to be wound on it. It is observed that winding under a tension of about 20 Lbs. is satisfactory. This can be done by improvising some friction to the string or by adding a weight to keep the string under tension. An experienced person can wind the string uniformally on a cage. This small tension will be helpful as the string on wetting will expand. The joining of two pieces of strings by knot should be avoided. These should be joined by twisting the fibres. The ends of the string after completing a winding on a piece, are fixed below the layer of string on the iron strip or the iron bar.

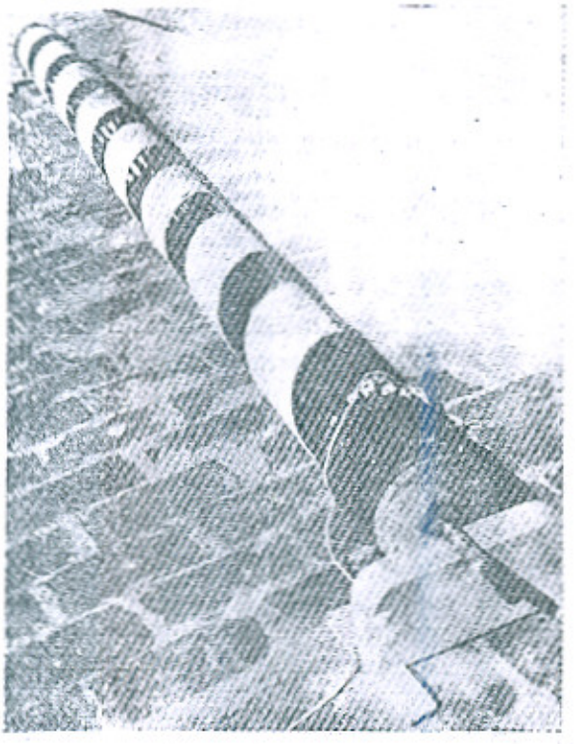


Figure 21. Arrangement for winding coir on an iron cage.

Protection of winding of the coir string

All the failures of a coir string strainer in addition to its choking and incrustation are due to the breaking of the string. Damage to a single string can cause the failure of a tubewell. It is thus necessary to observe all the precautions necessary for its protection. No weak or inferior string may be used. In order to avoid damages, while pulling out the casing or boring pipe, it is suggested that the windings of the string may be protected by some wire gauze. Even the gauze of iron gets rusted and can be a source of addition to incrustation. An alternative is to use double winding of the string. This no doubt affects the porosity and results in either the increase of depression head or some reduction in discharge, but it is a protection against the failure of string. This method is superior to providing a protection of iron gauze around it.

If it can be so arranged that the first winding is inclined at an angle of 30° to 40° and the second winding is straight as shown in Figure 22, the porosity of the windings will

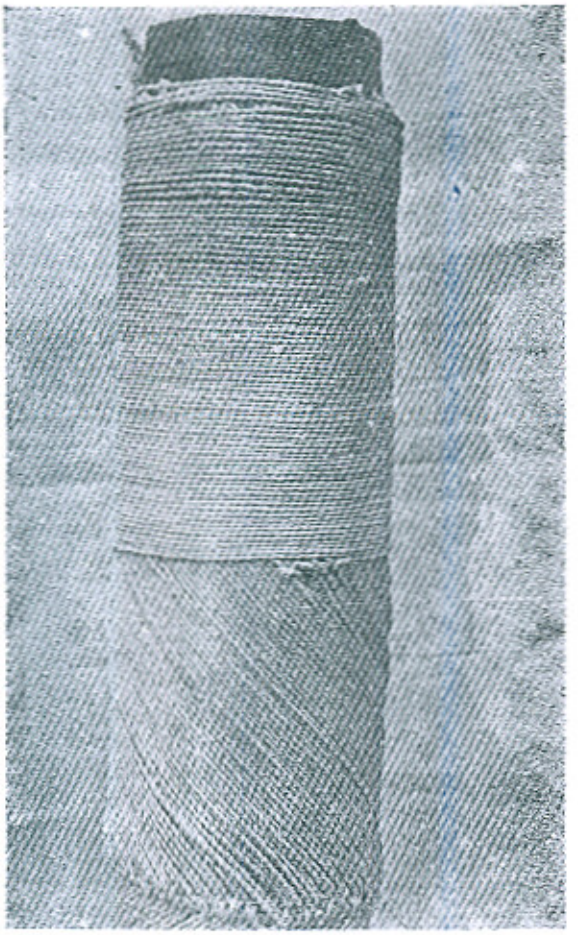


Figure 22. A system of double winding of coir string. The first layer of string is kept inclined.

remain high. This type of double winding is superior to straight round windings.

Careful inspection of the strainer before installation

A single defect in the string can cause failure of a tubewell. It is thus necessary that a careful inspection of the strainer may be carried out before it is lowered into the formation. It may be checked that there are no knots on the surface. Ends of the string are tightly fixed. The winding is uniform. It is not loose. The string is of uniform diameter within the tolerance limit of size equal to 1/8 to 2/8 inch. The two strings are not separate to yield empty space of more than 1/32 to 1/64 inch. The second winding if in the same direction as the first one will lie in the groove of the first winding. The coir is genuine and not a mixture of other kinds of fibre.

Fitting of the socket also needs careful inspection. It may not have a loose fit and the two pieces may fit tightly together. The flanges may have proper threads. A careful inspection of the strainer and checking all these points at the time of its lowering, will ensure that no defective strainer is installed.

Other advantages of a coir string strainer

Corrosion occurs when two different metals are joined together and kept in the soil formation. Coir is an innert material and its cage is made of one metal. This is an advantages. In order to lower the cost of construction further, a coir string strainer may be installed even in place of a blind pipe. About 40 ft. of blind pipe at top is essential and in the rest of the bore coir string strainer can be used throughout the depth of the formation irrespective of the existence of clay layers, fine dirty sand or fine sand. Clay particles are held by cohesive forces and being low water yielding are not removed during pumping. This type of formation is usually blocked by a blind pipe. In the earlier, construction of tube-wells with slit strainer even the fine sand region was provided with a blind pipe. The strainer faced only the medium sand. A coir strainer can be kept throughout the length of the bore. Even the fine sands will contribute to the discharge of the well. A coir string strainer is cheaper and its replacement with blind pipe further lowers the cost.

Use of wooden strainer

When the Rasul Tubewell Project was in progress in 1945-1946, it became difficult to obtain brass sheets. Mr. Haigh, Chief Engineer of the Irrigation Department, introduced, wooden strainer cut out of seasoned shisham wood. Pieces of wood, 3 ft. long, six inches wide and 2 inches thick were selected. These were planned and then formed into a pipe. The two wooden pieces were joined by making a slit in one and a projection in the other as shown in Fig. 23.

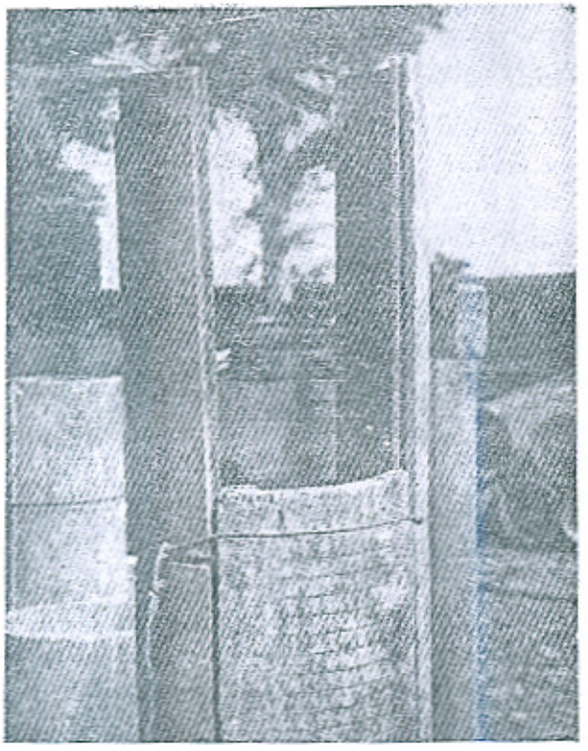


Figure 23. A wooden strainer with two segments pulled out.

In this way a pipe was made with 6 inches internal and 8.0 inches external diameter. Slits were cut in each wooden piece. These were 4 inches long and about 1/16 inch wide (Fig. 24). The open area of a wooden strainer attained was within 6 percent. While

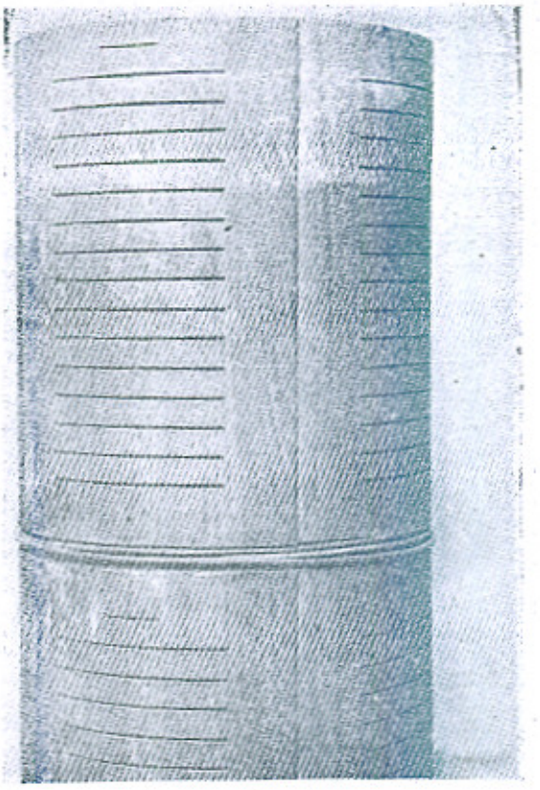


Figure 24. A specimen of wooden strainer with 4 inches long and 1/8 inch wide slits.

joining two pieces together, it was instructed to pull out two alternate pieces of wood and fit them in the next piece as shown in Figure 24. In this way one long piece of strainer was formed. The pieces were held in position by 2/8 inch galvanised iron wire. Some strainers of 10 inches diameter were also made. In some tubewells, telescopic strainers were used, the lower half length being of 8 inches outer diameter and the upper half of 10 inches diameter. The two pieces were joined by an overlap of about one ft., so that the 8 inches outer diameter strainer exactly fitted in the 10 inches outer diameter piece.

Iron strainer

A slit type iron strainer was never used after the experience on its rusting. At

attempt was, however, made to use an iron strainer with punched slits as shown in Fig. 25. Ungalvanised pieces, however, quickly got rusted and blocked the slits. The incrustation of this type of strainer after three months' location in water-bearing sand



Figure 25. Punched iron strainer. Slit width 1/16" to 1/8".

is shown in Fig. 26. Recently in 1960 iron strainer with wide slits equal to 1/16 to 1/8 inches and cut in groups of two or three slits have again been used in the tubewell project of Central Rechna Doab.

Gravel packed strainer

In 1953-54, a strainer was prepared by a Chief Engineer of Irrigation Department. The body of the strainer was made of iron bars, 3/8 inch in diameter and welded to cost iron flanges. The iron rods were provided with iron stiffners every one foot



Figure 26. Rust caused sticking of the shrouding materials around the strainer.

apart. The distance between two iron bars was kept equal to 1/16 inches. Strainers with the distance between the two iron bars kept equal to 1/8 and 2/8 inches were also made. The bars were covered with fine uniform gravels and later on with graded shingles, coarse grades kept adjacent to the rods followed by fine grades. The shingles were held in position by the use of 5 percent cement without sand. This gravel packing was about 2 inches thick. It was protected by a G. I. wire gauze on the outside. Each piece of strainer was 6 ft. in length. Two pieces were bolted together at the iron flanges. In figures 27 A, and B are shown the strainer with the inner iron bars exposed and a complete strainer with gravel filter, wire-gauge and the flanges.

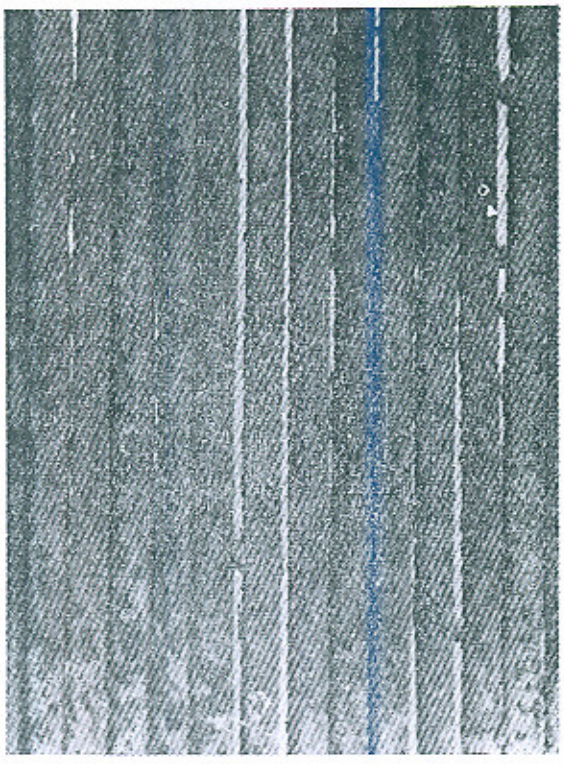


Figure 27A. Iron bars 3/8 inch thick 1/16 to 2/8 inch apart over which the gravel is pasted with the help of cement.

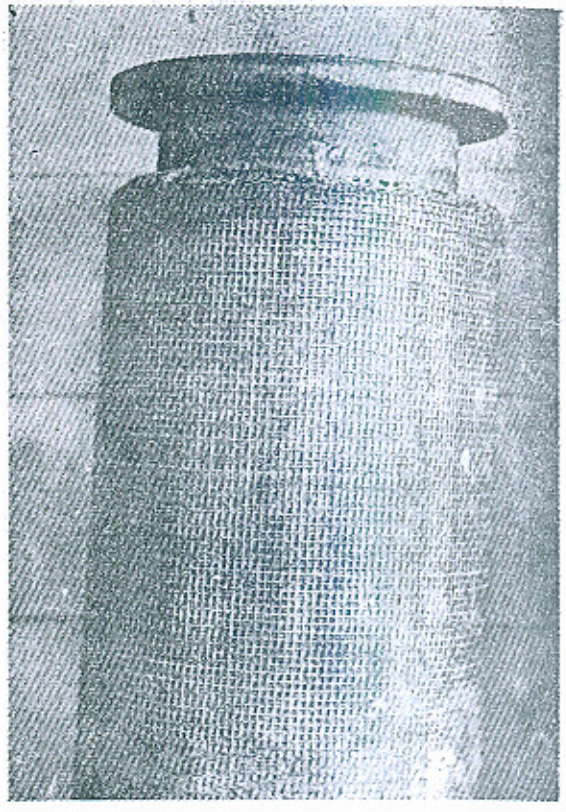


Figure 27B. A specimen of gravel packed Ghafoor strainer.

Development of plastic strainer

Recently tubewell strainer of other materials are also being tried. A plastic called the P.V.C. is being cheaply produced in many countries of the world. Its production has also started in Pakistan. Pipes of this material of any desired diameter are supplied in 20 ft. length. Each piece has a spigotted end so that two pieces can be joined together with a plastic solution. The two ends of a pipe to be joined are coated with a cementing emulsion and are then held in position, clamped together shown in Figure 28 for some time when a very strong junction is formed. These pipes are made in different diameters and can withstand different orders of pressure. In table 2 the cost of the P.V.C. pipes as supplied by the Imperial Chemical Industries, London, in the year 1963, is given.

TABLE 2

Price list of the P.V.C. pipe by I.C.I.

S. No.	Bore Size		Safe pressure	Cost per ft. in rupees
1.	3″	Class 'C'	300 ft.	2.76
2.	4″	,,	,,	4.08
3.	5″	,,	,,	5.92
4.	6″	,,	,,	8.10
5.	8″	,,	,,	13.58
6.	6″	Class 'D'	400 ft.	10.47
7.	8″	,,	,,	14.20
8.	6″	,, 'A'	100 ft.	5.08
9.	8″	,,	100 ft.	8.40
10.	6″	,, 'B'	200 ft.	6.22
11.	8″	,,	200 ft.	10.04

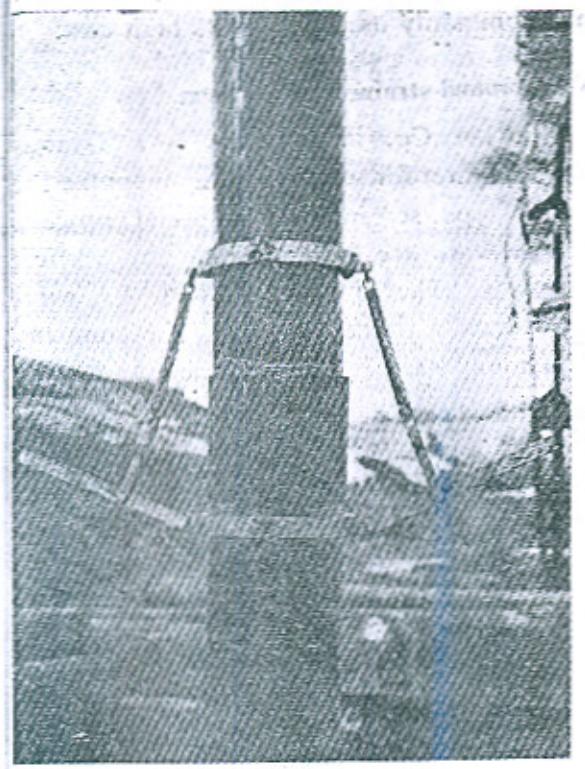


Figure 28. Joining of two pieces of P. V. C. Pipe by an emulsion.

packed

, is given.

I.C.I.

Cost per ft. in Rupees
2.76
4.08
5.92
8.10
13.58
10.47
14.20
5.08
8.40
6.22
10.04

Its present costs must have been further reduced as its manufacture is becoming very common. Whenever a P.V.C. pipe is to be converted into a strainer slits are cut on its body with standard cutters which are available in different sizes. Slits equal to 1/32 or 1/16 inches wide and 3 inches long can easily be made on the body of a P.V.C. pipe. The material is soft and can easily be cut so that 20 ft. long pipe can be provided with slits within a few hours. An improvised device to cut slits on a strainer is shown in Fig. 29. Blind pipes of the same material can also be used. It is also possible to make a string type strainer with this plastic.

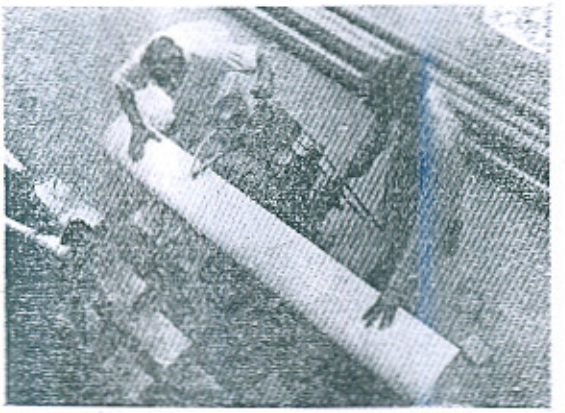


Figure 29. Slit cutting in progress on cement asbestos pipe.

Strainers of cement asbestos pipe

Cement asbestos pipes are now manufactured in the country. These are supplied in lengths up to 10 ft. and are made to any diameter. Two pieces can be joined by a spigot type joint or by sockets with cement or preferably with bitumen. When a cement asbestos pipe has been recently spin and it

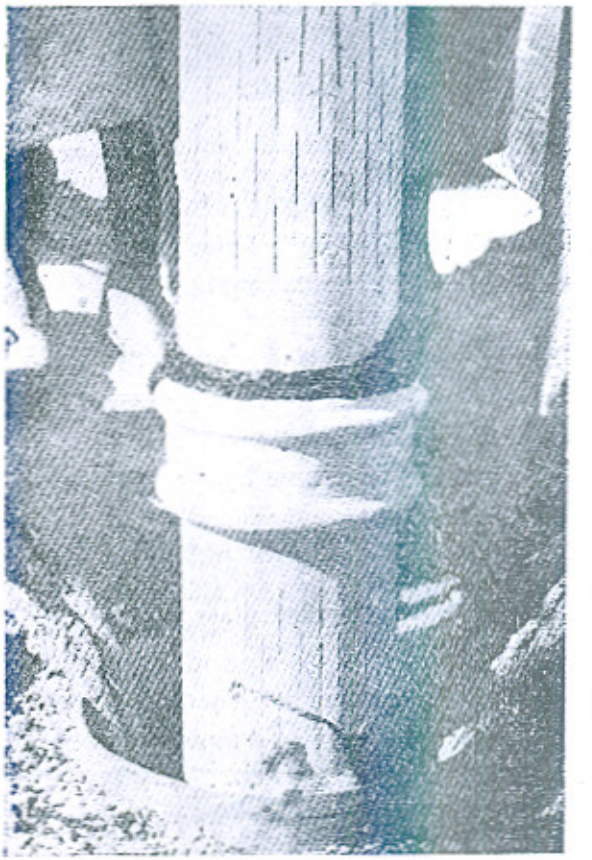


Figure 30. Slit type cement asbestos strainer, showing the joining of two pieces with sprigot joint and bitumen

has not yet completely hardened it is easy to cut slits in its body. A pipe of cement asbestos after curing for 3 or 4 days can be subjected to the cutting of slits with the help of standard cutters. (See Fig. 30).

It is also noted that it is easy to cut 2.0 inches diameter holes or slits 6 inches long and $1\frac{1}{2}$ inches wide on its surface as shown in Fig. 30A. These holes or slits can have

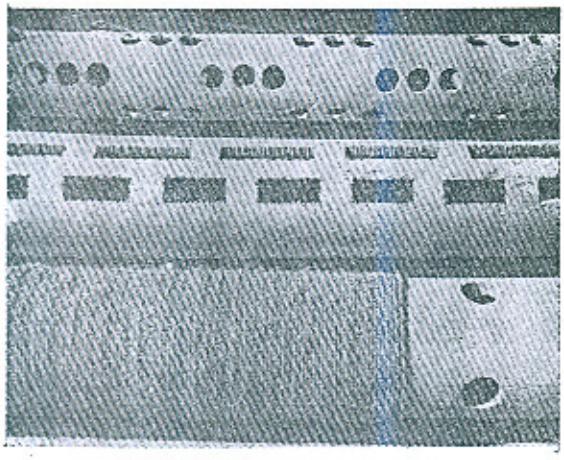


Figure 30A. Cement asbestos pipe with rectangular & round holes. A piece on which coin string is wound to make it into a strainer.

winding of coir string. Thus a strainer and pipe of the same material can be used.

The two pieces are joined by two types of sockets. One type is a German patent use of which is helpful to pull out the strainer or pipe. This is not possible by using ordinary socket which no doubt is leak tight but cannot stand the tension of pulling upward.

Strainer of Epoxy bonded glass fibres

A slit type strainer has been made by using glass fibres cemented together with epoxy resin. These strainers are now being used by Wapda in their tubewell. This type of strainer is imported.

Stainless steel strainer

Where the waters are corrosive or acidic, stainless steel strainer is used otherwise it si not commonly used due to its high cost.

Wire wound strainers of Johnson

Johnson Co. in America is a famous manufacturer for screens. They manufacture string type screens by a special process. The strings are held together by vertical supports. The slits are formed by wires welded on a frame (fig. 31). The company can supply strainers of all diameters with any

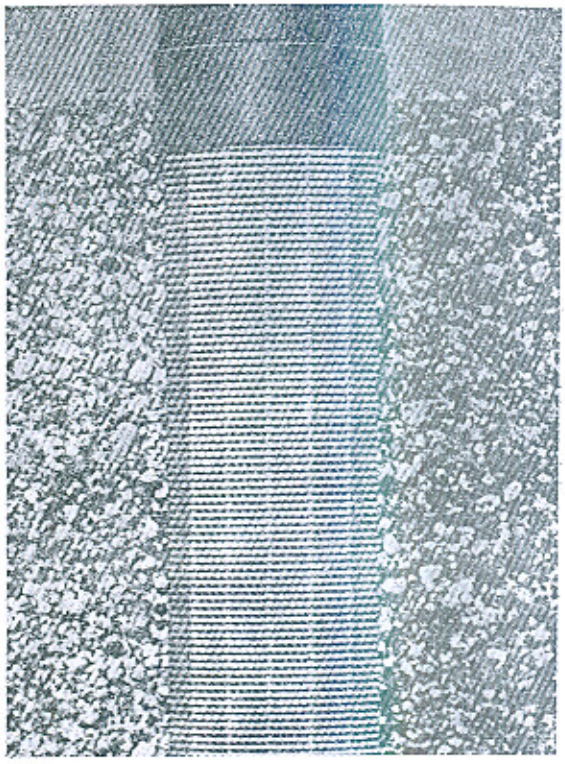


Figure 31. Johnson Co. in America Manufactures Wire wound strainer.

size of slit opening contructed in various non-corrosive materials.

Cost of different types of strainers

The cost of strainers fluctuate with the cost of the raw material. It also varies with change of specifications. The cost is lowered by using thin sheets or inferior materials. An approximate cost per foot

length of strainer of different materials made by using nearly standard materials is shown in Table 3.

TABLE 3

The relative cost of different types of strainer.

S. No.	Material	Diameter		Cost in Rs. per ft.
1.	Brass strainer, slit type.	8.0″ 7.75″	outer inner	40/-
2.	Brass strainer, slit type	10.0″ 9.75″	outer inner	60/-
3.	Brass strainer, wire wound	8.0″ 7.75″	outer inner	45/-
4.	— do —	10.0″ 9.75′	outer inner	65/-
5.	Iron pipe strainer, thickness, 2/8″	10.0″ 9.5″	outer inner	60/-
6.	Gravel packed strainer	12.0″ 7.5″	outer inner	70/-
7.	— do —	10.0″ .5″	outer inner	60/-
8.	Stainless steel strainer.	8.0″		150/-
9.	Wooden strainer	8.0″ 6.0″	outer inner	25/-
10.	— do —	10.0″ 8.0″	outer inner	35/-
11.	Coir string strainer single winding with iron gauze protection	10.0″	outer	15/-
12.	— do —	8.0″	outer	12/50
13.	— do —	6.0″	outer	10/-
14.	Cement asbestos	10.0″ 9.0″	outer inner	13/-
15.	— do —	6.0″ 5.0″	outer inner	7/-
16.	Plastic strainer P.V.C.	6.0″ 5.0″	outer inner	12/-
17.	Glass fibre bonded with Epoxy	8.0″ 7.5″	outer inner	66/-

Cost of a strainer in comparison to life expectancy

Tubewells installed in the Indus formation have not been found to last indefinitely. A common observation is that a strainer within five years deteriorates, resulting in fall in its yield by 15 to 25 percent. Within ten years of its operation, the fall in yield is about 40 to 50 percent. Many tubewells start to yield uneconomical discharge after 10 to 15 years of their installation. In the history of tubewell installation in this country there are very few examples of tubewells yielding economical discharge after fifteen years. In table 4 the performance data of some tubewells installed in various regions of the Indus plains are given. It shows the deterioration of a tubewell and fall in its discharge.

A strainer has to be replaced after fifteen years if not earlier. This is the estimate for the useful life of a strainer but not of the pumping machinery. It is thus no use to make the strainer extra strong and costly if it is to last for such a limited period.

Causes of failure of a tubewell strainer

There are two main causes of failure of a tubewell strainer to yield water continuously. These are the corrosion of the metal used and the incrustation of strainer. These are two distinct reactions, one is more of an electro-chemical nature and the other is due to physicai, chemical and biological causes.

Corrosion of a metal screen

Corrosion is of three kinds:

(*i*) Direct reaction of metal with elements present in water.

(*ii*) Dissolving of metal of an alloy with reactive water.

(*iii*) Electrolytic corrosion.

TABLE 4

Deterioration of tubewells in West Pakistan.

Scheme with type of strainer	Year of starting operation	No. of T.W. installed	Designed discharge	Average disch. after 5 years	%decrease in disch. 5 years	Average Disch. after 10 years	%decrease in Disch. after 10 years
Karol Project Brass ..	1940	20	1.5	1.2	20	0.9	55
Upper Chenab Canal Brass ..	1947	36	2.0	1.1	32	0.5	70
	1954	24	2.0	1.4	30	0.9	55
Rasul Scheme (Brass) ..	1954	1142	2.0	1.57	21.5	1.0	50
Rasul Scheme (wooden) ..	1954	214	2.0	1.2	40	..	..
Dera Ismail Khan Brass ..	1957	60	3.5	2.2	20	1.5	50
F. A. O. Scheme Chuharkana (Brass). ..	1953	24	2.0	1.72	14	1.2	60
Central T. W. Scheme ..		21	3.5	2.2	37	..	..
Along drains (Ghafoor) ..	1960	40	3.0	2.0	33	..	..
Along drains (M. S. Plate) ..	1960	22	3.5	1.7	50	..	..
Shadman Scheme (M. S. Plate)	1960	92	2.0	1.5	30	..	..
			3.0	1.8	40		
			4.0	2.4	40		
Gaja area G. M. Barrage (Coir). ..	1960	7	1.6	1.2	25	..	..
Lahore Border Area (Coir) ..	1960	40	1.75	1.65	7	..	..

Note:—The discharge of tubewells after 5 years is for the working tubewells. Those failed during this period are not taken into account.

Oxygen and Carbon Dioxide are the two main gases dissolved in water, with iron to form iron oxide. Carbondioxide forms a weak acid which reacts with metals. A common cause of corrosion of iron pipe or a strainer is its rusting. It forms pitting and holes in the iron pipe. (fig. 32). The iron piece, slits of an iron strainer are eaten away (fig. 33). Metals like iron or steel react with oxygen and get corroded.

Non-ferrous materials like brass which contain zinc are also liable to corrosion and pitting as zinc is reacted by acidic or alkaline

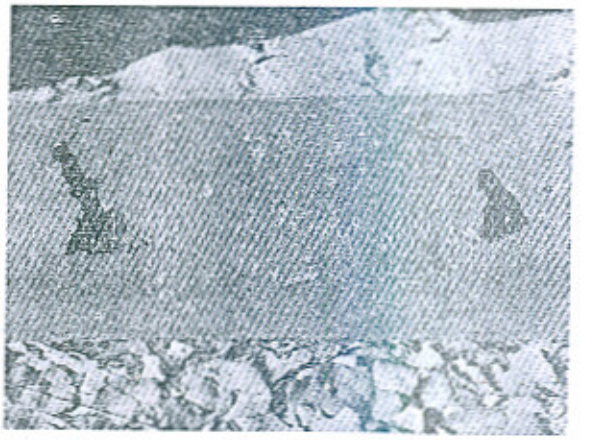


Figure 32. Iron pipe in tubewell gets corroded after some time. This specimen was taken out of a tubewell.

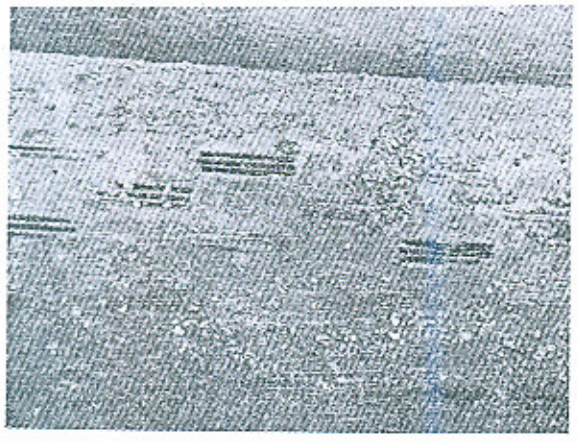


Figure 33. Iron strainers were made by cutting a group of three slits. The incrusted strainer was taken out after 2 years of installation in the formation.

water.

The most important cause is the electrolytic corrosion. Actually it is the main cause of the trouble.

Whenever there is a difference of potentials, current flow starts and ions from this region of high potential move to the regions of low potential. Two different metals have a difference of potential. When these are joined, ions from one metal are detached to be deposited on the other. The metal which looses ions is corroded. If we connect iron with brass as is a very common practice in tubewells installation, iron looses ions and these get deposited on brass. This causes corrosion of iron pipe and incrustation on brass strainer. Difference of potential can also appear even in the same metal (Fig. 34 A). An iron pipe having slightly different physical or chemical constituents or the pipe with cut slits or threads can have a different potential as compared to the rest of the pipe, although the material is apparently the same. This causes ionic flow of current (Fig. 34 B) and consequent corrosion of metals. In table 5 are given the order of metals which when

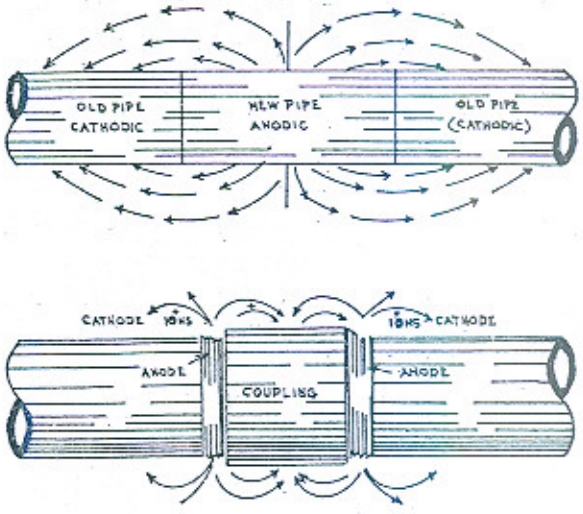


Figure 34A. Ionic flow from high to low potential.
Figure 34B. Threads in a pipe are at high potential than the pipe.

joined together will cause corrosion of the next one.

TABLE 5

Corrosion tendencies of metals.

1. Magnesium (Corroded end-Anodic).
2. Aluminum.
3. Zinc.
4. Cadmium.
5. Iron.
6. Chromium Iron Active (Stainless Steel).
7. Chromium Nickel Iron Active.
9. Solder.
8. Tin.
10. Lead.
11. Nickel.
12. Brasses.
13. Bronzes (Everdur Metal).
14. Nickel Copper Alloys (Monel & Super-Nickel).
15. Copper.
16. Chromium Iron Passive (stainless steel).
17. Chromium Nickel Iron Passive.
18. Silver.
19. Gold.
20. Platinum (Protected and Cathodic).

Some metals or alloys of metals are resistant to corrosion. Johnson has given the following alloys or metals in order of their resistance to corrosion.

TABLE 6

Metals or alloys in the order of corrosion resistance.

1. Monel Metal (Approx. 70% Nickel, 30% Copper).
2. Super Nickel Metal (30% Nickel, 70% Copper).
3. Everdur Metal (96% Copper, 3% Silicon, 1% Manganese).
4. Stainless steel (74% Low Carbon Steel, 18% Chromium, 8% Nickel). (Provided the ground and water conditions and screen openings are such that the protective film is maintained).
5. Silicon Red Brass (83% Copper, 1% Silicon, 16% Zinc).
6. Anaconda Red Brass (85% Copper, 15% Zinc).
7. Common Yellow Brass (Approx. 67% Copper, 33% Zinc).
8. Armoc Iron.
9. Low Carbon Steel.
10. Ordinary cast iron.

The solution to resist corrosion is either to use a single metal strainer and pipe or use non-reactive materials like Plastic, P.V.C. pipes, Cement Asbestos, Wood, non-corrosive, metals like brass etc. Coir string except the iron cage is also an innert material.

Incrustation

This is the second and the most important cause for the failure of a screen to yield water. It is due to the deposition of materials around the opening of the screen or in the water bearing formation round about it. Incrustation takes place sooner or later regardless of the material used in the screen. If the screen is of corrosive material such as iron, the incrustation is hastened. If the formation contains more fine materials the incrustation is quicker. Clay particles of colloidal range are electrically charged possessing both positive and negative charges. These particles are smaller than 1/1000 mm. These are much smaller than the fine sand, the average size of which is 2/10 mm. The pores between individual particles are also bigger than 1/1000 mm. The result is that fine clay particles can pass through the pores of sand.

Graton and Fraser in 1935 tried to work out the size of pores assuming particles to be perfectly sypherical and placed under different order of packing as shown in Fig. 35 A. The possible packing are shown and their pores are shown in

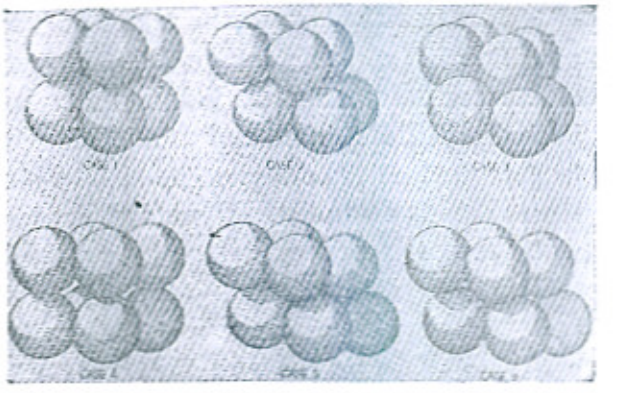


Figure 35A. Graten and Fasal experiments with round balls to show the formation of voids.

Fig. 35 B. According to this if R is the radius of the particles, volume of void in terms of R is worked out. These results are shown in table 7 which shows that if the volume of the cell lies between $8 \times R^3$ to $5.7R^3$ then the volume of void will lie between $3.8R^3$ to $1.5R^3$. The volume of void is 48 percent maximum and 26 percent minimum.

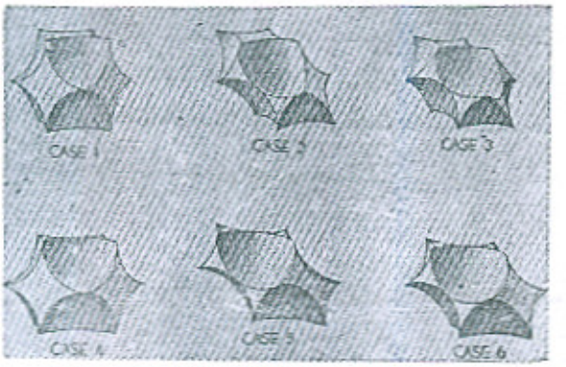


Figure 35B. The size of the voids compared with the ball is shown for six different types of packing.

The sand particles, however, are not spherical but are angular and for this reason can be packed in more compact form and can have small size of voids. The clay colloidals are still smaller and can easily pass through the pores of fine sand. Another property of fine clays is that their particles are electrically charged, possessing both negative or positive charge and thus deposit on the metal screen or even join together with the electrical bond. Sands are electrically innert and yet can get entrapped within the charged clays and form a hard mass and may deposit around the strainer.

Incrustation as a result of the presence of salts

The salts of calcium and magnesium, particularly the carbonates are very common in the soil formation. These are normally insoluble in water but in presence of carbon dioxide, carbonates are converted into bicarbonates which are soluble in water. Carbon dioxide gets dissolved in water. The cooler is the water and more is the pressure, large is the volume of this gas which can be dissolved. Carbon dioxide forms a weak carbonic acid which reacts with the calcium and magnesium carbonate (lime stone) to form soluble calcium or magnesium bicarbonates. This solution again has a property that under decrease of pressure it loses some carbon dioxide so that the bicarbonates are again converted to carbonates which being insoluble settle in water. When a tubewell is operated, decrease of pressure is greatest near the screen, so that carbonates settle round the strainer and form a very hard mass. Deposition of calcium carbonate helps to form incrustation and choke the strainer. Such incrustation on a piece of coir string strainer extracted out of Gaja area in Ghulam Mohammad Barrage is shown in Fig. 36. This was the strainer taken out after about three years of operation. The formation contained fine clay particles and the groundwater had large amount of

TABLE 7

Porosities of the various packings.

	Arrangements of square layers			Arrangements of simple rhombic layers.		
	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
Volume of unit cell ..	$8.00R^3$	$6.93R^3$	$5.66R^3$	$6.93R^3$	$6.00R^3$	$5.66R^2$
Volume of unit void ..	$3.81R^3$	$2.74R^3$	$1.47R^3$	$2.74R^3$	$1.81R^3$	$1.47R^3$
Porosity ..	47.64%	39.54%	25.95%	39.54%	30.19%	25.95%

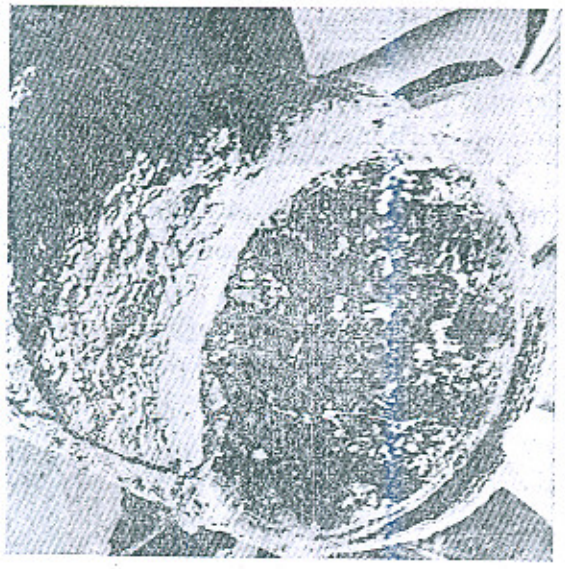


Figure 36. A piece of coir string strainer heavily incrusted after 3 years of the operation of well in a formation containing salts more than 10,000 ppm.

dissolved salts. The incrustation included the shrouding particles cemented together.

Another example in Fig. 37 is that of a brass strainer extracted from Chej Doab near Sargodha area. This incrustation was formed within five years.

A specimen of incrusted iron strainer extracted after three years of its installation from Shadman Scheme area near Sheikhupura is shown in Fig. 38. This strainer

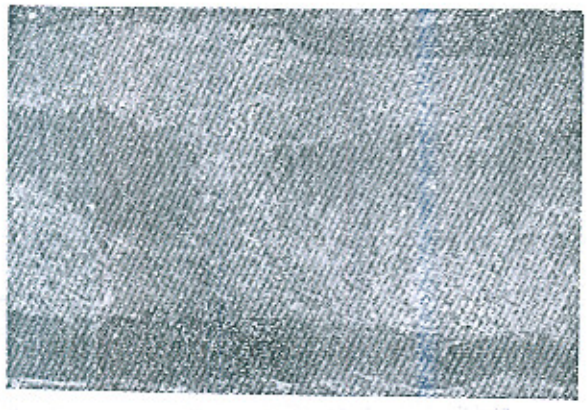


Figure 37. A specimen of incrusted brass strainer taken out from Sargodha area after five years of working.

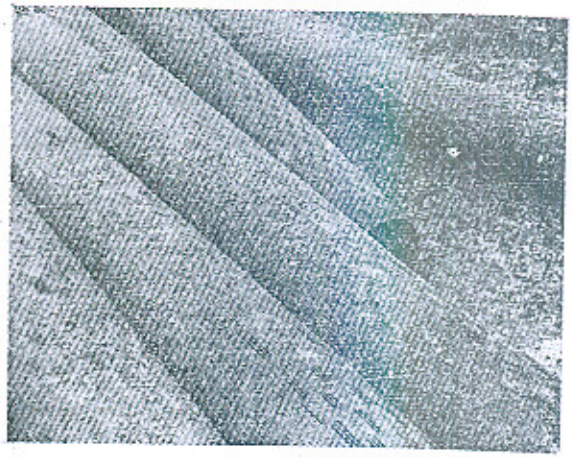


Figure 38. Specimens of iron strainer extracted from Shadmen scheme near Sheikhupura.

showed the incrustation as well as the corrosion.

Incrustation thus can take place on all materails including coir string which is non-reactive. No specimen of the formation around the strainer has yet been extracted but it is definite that the formation around a strainer also gets incrusted and thus stops to yield water. There are instances when a tubewell, yielding very low water, was extracted and examined, its strainer had no serious incrustation. In such cases most probably the formation around it had got incrusted.

Bacteria help in the incrustation

There are some types of organism which grow by feeding on iron. There are also sulphate reducing bacteria which produce sulphurated hydrogen, which is a corrosive gas. Biological causes also help in the formation of incrustation.

Material and salts found in the incrustation

The incrustation of the tubewell strainer pulled out was examined physically as well as chemically. It was noted that there was always about 40 to 50% of the formation materials such as sand, silt and clay, about

20% was the lime, made up of calcium and magnesium carbonate and about 6% were iron and other salts. The chemical analysis of the incrusted material is given in table 8. The location of tubewells was in good quality area (salts about 500 ppm) along U.C.C. at R. D. 25900, in fairly saline water (salts about 5000 ppm) near Sargodha and in highly saline groundwater (salts 20,000 ppm) of Gaja. The salts of calcium, magnesium, iron, alumina, combined with sulphates, carbonates and chlorides were found. The proportion of different materials from various sites was very variables but the nature was the same. It is often noticed that the iron discharging pipe also gets plastering of incrustation on the inside. A specimen of this material was examined and its results are also given in table 8(5). It was found to contain the same material as around the strainer.

Methods to eliminate corrosion and incrustation

Many methods have been suggested to deal with corrosion and incrustation. These are not discussed here but it is worth while to state that the use of non-corrosive materials can only avoid corrosion. Plastic P.V.C., Cement Asbestos, Coir string and such other innert materials will not corrode. Incrustation is, however, unavoidable. Certain measures are no doubt helpful to reduce the period of incrustation. The measures are:—

(*i*) the use of screens with large percentage of open area to permit water flow with with least resistance.

(*ii*) Use of shrouding around a well screen. It will be subsequently discussed.

(*iii*) Use of low rate of pumping.

(*iv*) Spreading the pumping load to a large number of small wells rather than pumping a great volume from a single well seems to be another solution.

(*v*) Occasional chlorination of the wells may reduce the bacterial life activity.

These are some measures, which prolong the period of incrustation.

TABLE 8

Chemical Analysis of Incrustation of Tubewell strainer.

S. No.	Tubewell No.	Site	Quality of G. W. Total solids, ppm.	Period of operation or remaining in the formation (app.)	Material of strainer & B.P.
1.	8 C	U. C. C. R. D. 259500	500	5 Years	Strainer Brass B.P. Iron.
2.	30 D	L. J. C. R. D. 259000	5000	5 ,,	,,
3.	..	Bahawalpur	500	8 ,,	,,
4.	No. 2	Gaja Area.	20,000	3 ,,	Iron Cage.
5.	No. 3	,, ,,	20,000		Coir
6.	T. W. Iron pipe.	at all site.			String.

Physical and Chemical Analysis.

(1) *Tubewell No. 8C. percentage of total.*

Sample No.	Silica or Sand	Iron oxide or rust	Copper oxide	Aluminium	Calcium carbonate	Mag. carbonate
1.	49	28.5	0.95	1.31	12.0	4.0
2.	51	31.0	7.0	..	11.0	..
3.	50	20.0	6.0	..	22.0	..

(2) *Tubewell No. 30 D, percentage of total.*

Silica free	Silica combined	Iron oxide Fe_2O_3	Sod. (Na.)	Pot. (K.)	Sulphate $(SO)_4$	Ca. Oxide (CaO.)	Mag. Oxide	Sulphure
15.3	2.11	13.9	0.94	0.70	9:04	35.6	2.4	Traces

(3) *Tubewell in Bahawalpur Region, % of Physical and Chemical shown, separately.*

Physical			Chemical			
Sand	Silt	Clay	Insoluble residue	CaO	Iron oxide (Fe_2O_3)	%loss on ignition
42.0	48.4	9.6	63.57	14.52	5.87	2.24

(4) *Gaja Area Tubewell No. 2*

Physical, %

Gravel	C. Sand	M. & F. Sand	Silt	Clay
6.6	54.0	21.5	14.5	3.4

Chemical %

$CaCO_3$ Lime	Iron and Alumina	Mg.	Carbonate CO_3	Bi-Carbon ateate	Chloride	Sulphate
46.0	41.4	0.1	0.02	0.02	3.8	1.6

(5) *Chemical Analysis of material from the inside of a pipe.*

Sand, Silt and Clay	Iron oxide	CaO	MgO	Loss on Ignition	$Mn.O_2$
86.9	2.4	1.5	1.3	7.2	Traces

Atomic Energy: New Promise for Pakistan

By DR. I. H. USMANI

Dr. I. H. Usmani, Chairman, Pakistan Atomic Energy Commission, sometime back published an informative article on the power resources of East and West Pakistan. He put forth data to prove that the present day yardstick to measure economic development of a nation is the per capita consumption of power.

The conditions of natural resources of Pakistan are such that Atomic Energy is more feasible than the development of conventional power resources particularly for East Pakistan which lacks natural power resources. The article contains a lot of useful information and scientific data and for this reason we have extracted this article for the benefit of the readers.

The present-day standards of living or the economic conditions of a country is measured on the basis of per capita consumption of power in that country. The United States and Canada have a per capita consumption of power of about 5000 to 6000 units (Kwh) per year. Canada has actually 6420 units, United States 5340, United Kingdom 3266, France 1844, Brazil 429, Turkey 131 and Pakistan 48. The statement that per capita consumption of power is the yardstick of economic development and comparative growth, is borne out by these figures. In fact, it is found that a linear relation exists between per capita consumption of power and annual production.

Now let us examine the conditions in Pakistan.

In our country the present rate of growth of population is 2.4 per cent per year. Suppose we are successful to reduce it to 1.5 per cent per year. Then by 2000 A.D., after 35 years, West Pakistan will have a population of about 96 million.

Now let us consider the development of power resources.

Suppose we start doubling per capita consumption every 8 years up to 1975, then doubling every 10 years between 1975 to 1995 and finally double it within the next 12 years between 1995 to 2000. The per capita consumption works out to about 1000 units. Then after 35 years, we would be about 35 per cent developed than Japan of 1963. Even to attain this much development in the next 35 years we must generate 32 million k.w. operating at 50 per cent plant factor to give a per capita consumption of a thousand units by the year 2000 A.D.

Power from Hydro-sources of West Pakistan

West Pakistan is fortunate in having a very big hydro-potential but unfortunately this hydro-potential is confined to the relatively inaccessible hilly regions of the north and the north-west. If for arguments we assume that out of the 25 mkw accepted figure of

planning commission we arrange to exploit 10 mkw as commercialy feasible, then in the next 35 years, it would be necessary to build at least five Tarbelas before the century is over. This is a fantastic target as a dam of the size of Tarbela takes at least ten years to build besides the difficulties of loans etc. Even if we assume it to be possible then by the end of the century we can expect generating about five million k.w. through hydro-resources out of our requirement of about 32 million k.w.

Power from Natural Gas Resources

The proven natural gas resources of West Pakistan are considered to be of the order of about 14.2 million million cubic feet (m.m.cu.ft.) of which the Sui gas, which can be piped or used for power generation is of the order of 9 to 10 m.m.c.ft.

In the last 19 years we have discovered 14.5 m.m.c.ft. of gas or its equivalent of Sui gas quantity about 10 m.m.c.ft. Suppose in the next 35 years we find another 10 m.m.cu ft. then we have a total reserve of 20 m.m.cu.ft. of natural gas. Suppose we burn 70 per cent of these deposits for generating power, then we can generate about 8 million kilowatts from the natural gas.

Power from Coal Resources

Our deposits of coal are very poor in quality. So far the known deposits are of the order of 300 million tons. Suppose we discover another 300 m. tons and suppose then coal can be washed off the sulphur, carbonized and made fit for use in boiler then using 70 per cent of these 600 m. tons of coal we can get power generation of the order of 4.6 million k.w.

Oil Resources

As for the use of oil, we have spent not less than 40 crores on oil exploration and so far we have got only gas out of this effort. The Attock oil fields in Potwar area can meet about 20 per cent of our indigenous demand and 80 per cent of our oil requirement has to be imported. Thus out of our total resources of Hydro (5 mkw) and Gas (8 mkw), Coal (4.6 mkw) we can at the most generate 17.6 million k.w. during the next 35 years against our requirement of 32 million kw. There will still be a big gap of 14 mkw.

Thus I find no possible escape from the conclusions that in the long-term planning for power, there is no alternative for West Pakistan but to look optimistically for future deposits of gas and to go ahead with hydro-construction and yet not to ignore nuclear power.

Power Requirement and Resources for East Pakistan

The position for East Pakistan is not only hopeless but completely bleak. The present per capita consumption of East Pakistan is about 16 units (kw) only. If we apply the same arguments of growth of population for this area, then the power requirements of East Pakistan by 2000 A.D. will be of the order of 16 million kw. The present-day generating capacity of the area is only 350 Mega watts (0.35 mkw.)

Its Natural Resources of Power

The Hydro. Although there is a lot of water in East Pakistan there is no hydro-potential. The only such potential of Chittagong Hill Tract near Kaptai we have already tapped. The total hydro-potential of the area is only 160 m.w.

The Gas. The proven reserves of gas are of the order of about 4 m.m. cu.ft. If we assume that we discover double this quantity and then consume 70 per cent of it then we can expect to generate 2.4 million kw. of power.

The Oil. So far exploration for oil has been a failure in East Pakistan.

The Coal. We have discovered about 200 to 700 million tons of coal but unfortunately it lies buried at a depth of 3000 to 5000 ft. which makes it impossible of economic mining. The experts have stated that mining any sizable quantity of coal by 1975 will involve an initial investment of $60 million to get 2 m. tons of coal per year. Suppose between 1975 to 2000 we can step up reduction to about 10 m. tons. Adopting this costly procedure to get about 10 million tons of coal, then we can get a power of only 1500 m.w. by consuming 70 per cent of the mined coal.

Economic Cost of Nuclear Power

In Asia per capita availability of fossil fuel is about 10% of that of Europe. The Nuclear Power is thus needed by the Asian countries more than the European countries. However the Nuclear know-how is available only in Europe, the United States and the Soviet Union. These countries do not need Nuclear Power so badly. In spite of the fact that fossil fuel is very cheap in United States, that country is going in for Nuclear Power in a big way. The reason is that Nuclear Power is going to be a cheaper source of power generation. Big Nuclear power station of 500 to 1000 M.W. capacity are already a cheaper sources of Power generation than the conventional power stations.

Now let us consider the case of Pakistan. Our studies showed that under the present condition of financing the Nuclear Station of about 130 to 150 M.W. capacity can produce power competitive with thermal power stations. The Government has sanctioned one 137 M.W. Nuclear Power Station for Karachi in West Pakistan and another for 140 M.W. Nuclear Station for Roop-pur (Pabna district) in East Pakistan. The cost of the Karachi plant will be of the order of $65 million of which nearly $51 million will be in foreign exchange.

Despite the fact that this capital cost is more than double the capital cost of a gas fired power station of equivalent capacity, the Karachi Station will be able to produce power at about 3½ paisa per K.W. at 70% plant factor.

The cost economies of 140 M. W. Roop-pur Power Station will be more favourable.

Other Uses

In the near future Nuclear Power will open out a technology of dual purpose power cum desalinization of sea water. If this thing is economically possible, then the Mekran Coast will become an attractive place for the migration of the population of West Pakistan.

By-Products of Power Reactor

By Fission of Uranium in a reactor, we get plutonium. This stuff is as fissionable as Uranium itself. So that Uranium in a reactor breeds another atomic fuel as a by-product. Plutonium is recovered by re-processing of the spent fuel element of Uranium in a chemical plant and can be recycled back as enriched material into a Uranium reactor to be used as such without Uranium as what is known as fast Breeder Reactor United Kingdom has already sanctioned a prototype 250 M.W. breeder reactor at Dounrey using pure plutonium as fuel. By 1980 such reactor may come into the market.

Production of Radio Isotopes

Radio Isotopes is another by-product of the reactors. These have vast utilization in agricultural, medicine, engineering etc.

Institute of Engineers Pakistan

THIRTEENTH ANNUAL CONVENTION

The Thirteenth Annual Convention of the Institute of Engineers, Pakistan was held at Comilla with the usual enthusiasm and eagerness to present the contributions and to discuss the experiences of various members of the profession. It is a useful occasion for the young to learn from the experience and knowledge of the elder members of the profession. In this meeting 16 papers of varied nature from different members of the trade were submitted and discussed. Some of the papers are most informative particularly for the Engineers of West Pakistan. Brief excerpts from the papers and from the address of the General President are reproduced below.

B. M. Abbas Addresses the Engineers

Mr. B. M. Abbas, President, Institute of Engineers, addressed the Thirteenth Annual Convention. The Governor of East Pakistan was the guest of honour. Mr. Abbas stated that the recent years have witnessed stupendous technological advancement. A Nobel Prize winner has said that if Napoleon and Julius Caesar had met they could have discussed without difficulty almost all their military and political problems. The 2,000 intervening years made no difference; the world did not change. In today's world, 150 years later, they would be complete strangers, understanding nothing of anything. Because the whole phase of human life has changed in a few decades. For the first time, man is faced with the possibility of either banishing hunger and disease, thereby achieving *undreamt* wealth and dignity, or wiping himself out altogether. We now travel with supersonic speed, while our thoughts are transmitted at the speed of light. The greatest heat known in Napoleon's time had been the few hundred degrees of campfire; the greatest destructive power he saw, was of the primitive gun-powder. The heat of present-day atomic fusion is 15 million degrees centigrade and an H-Bomb can destroy whole cities. Modern science has put satellites on orbit which are gathering data from other planets. Man may soon land even on the moon.

Yet poverty, hunger and disease stalk vast multitudes in different parts of the world. In Pakistan, Government has launched an all-out effort to achieve self-sufficiency in food in the shortest possible time. More water, fertilizer, pesticide and credit are being provided to the farmers for this purpose.

In the search for more food, water has played and will play a vital role. Many water development projects have been taken

up in both wings of the country. The urgency of implementing the Tarbela Dam Project is obvious.

The menace of waterlogging and salinity in the West Pakistan is being tackled by providing adequate drainage and increasing the water allowance to leach the salts from the root zone of the crops. In this connection research needs continuation and to improve the methods of reclamation and to avoid pitfalls.

Protection against floods is another great problem which must be afforded quickly by the construction of marginal embankments and improvement of river channels. This plan need to be implemented with the greatest possible expedition. Cyclone is another natural calamity causing the greatest damages to the East Pakistan economy in recent years.

In East Pakistan, organized Irrigation has only recently been started. At present there is slow utilization of the Irrigation water by the farmers. All efforts should be made to reduce the costs of the projects and to shorten the period of construction. Local technical personnel should be encouraged to participate more actively than in the past in the planning and design of the projects.

Problems of the Engineering Profession

The Government have entrusted the Ministry of Industries and Natural Resources to enquire into the various problems facing the Engineers. The Institute will extend its fullest cooperation in this examination.

In the interest of the country development, Government should give serious attention to this matter. The formation of an all-Pakistan Service of Engineers which will pool the best engineering talents for development works seems to be a must. The service should be attractive enough to stop the present drain of technical personnel to go outside the country. There is great need for the proper growth of Pakistan Consulting firms. Government may consider the setting up of a National Contracting Corporation in which both the private talent and the private capital should be associated. A Corporation like this apart from saving substantial foreign exchange, will build up personnel who could, under a regular programme, be released for setting up new firms of contractors.

In the course of my visit to development works in both the wings of Pakistan I have found in general a sense of deep frustration pervading amongst the engineers. They feel that they have to work in unfavourable environment where they are placed under non-technical people who sometimes lack the knowledge and experience to understand their problems properly. They also feel that they have to discharge heavy responsibilities without corresponding authority and are kept out of the decision-making spheres of the Government. The upper strata of Governmental administration are impoverished by failure to include a substantial proportion of them.

Talking about the affairs of the Institute of Engineers, the President said that strong efforts have been made during the year to increase membership and the results have been encouraging.

EXCERPTS OF PAPERS

An Appraisal of the Inland Water Transport System in East Pakistan

By A. M. Mohammad Ghulam Kibria

East Pakistan with an area of 54,500

square miles almost half of which is situated below the 25′ contour line, is gifted with a perennial system of about 3,000 miles of inland waterways consisting of rivers and estuaries. In the four monsoon months of June, July, August and September when about 15,000 square miles of the low-lying areas remain under an average depth of 5 to 10 feet of flood water mainly due to overflow from the Ganges, the Brahmaputra and the Meghna systems as well as drainage congestion in swampy areas, the length of the waterways increases to almost 5,000 miles.

Most of the land in the Province is flat about half of it lying below 25 feet contour line. It would be interesting to mention that the coal has been discovered at a depth of 3,000 ft. which is about 300 million years old. From the data revealed by the explorations it is apparent that in the beginning of the Pleistocene epoch (about one million years ago), the drainage of the area was towards the west into the Arabian sea in the vicinity of the present Cutch area. It is believed that by the Pleistocene epoch a massive subsidence was caused by the geological force. The west bound drainage was drawn to the south along the two edges of this fault in the form of the Brahmaputra and the Ganges rivers.

Hydrological Characteristics

The average maximum discharge of the Brahmaputra at Bahadurabad, the Ganges at Hardinge Bridge, the Meghna at Bhairab Bazar are respectively 2.5 million, 2.5 and 0.35 million cubic ft. per second.

Average difference between the maximum and minimum water levels at these three sites are 30, 25 and 18 ft. During floods high velocity up to 10 ft. per second can be expected in these rivers.

It is estimated that about 2 billion tons of sediment is carried by the Padma—the combined Ganges and Brahmaputra rivers. The grain size of the suspended materials varies between 0.03 mm. to 0.001 mm. Even the bed samples are too fine with D_{50} less than 0.1 mm.

The following Table by Prof. L. Van Bendegom of Holland gives relative data of discharge and sediment of important rivers of the world.

The rivers of East Pakistan are meandering one. The Meghna river drops its silt in Sylhet depression, so that its discharge is silt-free even during monsoon.

The precipitation occurs during monsoon from middle of June to middle of October. Some rain occurs during pre-monsoon period during March, April, and May and in post monsoon period between October and November. In an average year in Sylhet District, the rainfall per year is 200 inches and minimum towards Rajshahi equals to 60 inches. Temperature during winter range between 90 to 40°F during summer between 110° to 50°F and in monsoon period between 105°F to 55°F.

Humidity is generally high between 70 and 80 per cent wind velocity in Chittagong lies between 3 and 4 miles per hour in winter and about 8 miles per hour in summer. Cyclonic storms are expected during April, May, June and September. October and November.

Although country-crafts are still predominant for short haul traffic, rapid developments in the fields of mechanised passenger and cargo traffic have taken place since independence. It is estimated that there are now more than 300,000 countryboats and about 1300 mechanised vessels with a

S. No.	River	Water/year.		Solid matter, 10^6 tons/year.	% of solids inthe water flow (in mg/litre).
		$10^3 m^3$	maf.		
1.	Amazon ..	3000	2190	900	300
2.	Congo ..	1400	1022	70	50
3.	Ganges+Brahmaputra (Padma) ..	1000	730	2000	2000
4.	Yangtze Kiang ..	700	511	350	500
5.	Mississipi ..	600	438	600	1000
6.	Rio de La Plata ..	600	438	90	150
7.	Yenessei ..	500	365	10	20
8.	Mekong ..	400	292	800	2000
9.	Irawadi ..	400	292	400	1000
10.	Niger ..	250	183	75	300
11.	Volga ..	250	183	25	100
12.	Danube ..	200	146	80	400
13.	Hwang Ho ..	200	146	600	3000
14.	Indus ..	200	146	400	2000
15.	Euphrates+Tigris (Shat-el-Arab) ..	200	146	700	3500
16.	Rhine ..	80	58.4	3	40
17.	Nile ..	80	58.4	60	750
18.	Po ..	50	36.5	10	200
19.	Rhone ..	50	36.5	30	600

total Horsepower of about 200,000. Passenger traffic by service launches has grown very rapidly. There is a great future for mechanisation of countryboats and replacement of the old cargo steamers by integrated push to wing. At present more than 2.0 million and 21.0 million passengers are annually handled by P.R.S. Steamers and service launches respectively. Annual increase of IWT cargo traffic in recent years has been more than 10% and this is now about 2.4 million tons per year. This is directed mainly from Narayanganj to Chalna-Khulna and Chittagong. It is estimated that by 1970 the IWT cargo traffic may rise to more than 8.5 million tons mainly due to projected development of industries and mines. Existing navigation channels are classified into three groups. Only five artificially excavated navigation canals exist. Establishment of five modern inland harbours at Dacca, Narayanganj. Chandpur, Barisal and Khulna is a precursor to further developments in this field. EPIWTA has played a great role in development of IWT in East Pakistan since the creation of the Authority in October, 1958. Immediate need in this sphere appears to be modernisation of vessels, development of a number of link channels, introduction of bascule bridges, expansion of the terminal facilities at the five existing inland ports and development