Last year a similar study was conducted by keeping water-table at 3, 5 and 9 ft. below surface. The results were similar to those noted this year.

Yield of Cotton Crop under different Positions of Water-table

The yield of the crop was collected from each lysimeter. It was noted that the yield with water-table maintained at 9 ft. depth was the highest. It was assumed equal to 100 and the yield with other positions of water-table was compared with this. These results are shown in Table No. 3 and plotted in Figure 6 (*a*) and (*b*).

With rise of water-table in silty soil there was a sharp fall in the yield. With water-table at 5 ft., the yield in silty soil was less than 50 per cent. In case of clay soil, the situation was not so bad. This information was further confirmed by weighing the lint collected from the plants grown in each lysimeter. Weight of a single cotton plant freshly cut out of each lysimeter was also determined. These test further confirmed the results already arrived at. (*See* Table No. 4 below).

TABLE No. 3

Effect of Water-table and Soil on yield of Cotton (L.S.S.).

Soil	Silty						
Water-table in ft. ..	3	4	5	6	7	8	9
Yield in grm. per .. lysimeter.	18	50	82	115	136	176	198
% of yield w.r.t. .. water-table at 9 ft.	9.09	29.8	41.4	58.5	73.7	88.8	100
Soil	Clayey						
Water-table in ft.	3	4	5	6	7	8	9
Yield in grm. per .. lysimeter.	70	80	92	103	112	120	127
% of yield w.r.t. .. water-table at 9 ft.	55.1	62.9	72.4	81.1	88.2	94.5	100

TABLE 4

Effect of Water-table and Soil on Shoot and growth of Cotton variety L.S.S.

Weight of a single cotton plant in gms.

Soil/Water-table in ft.	3	4	5	6	7	8	9
Silty ..	80	140	195	242	288	315	240
Clayey ..	105	130	152	157	161	162	162

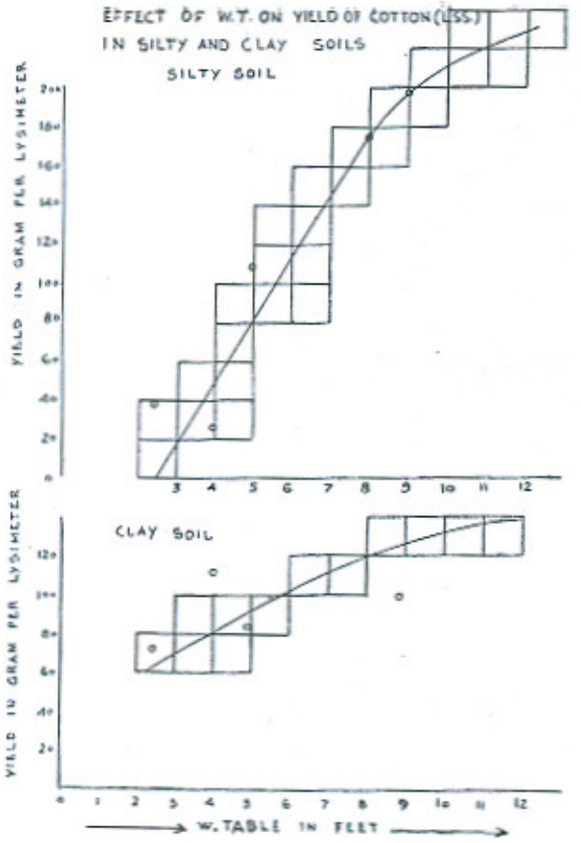


FIG. 6(a,b)

A study of the root formation was also carried out. It was not possible to extract all the roots of the plant. Some of the finer portions remained in the soil. In spite of this defect, when the root system was examined, it was noted that the plant having the deepest water-table had healthy, well-developed roots.

Optimum Depth of Water-table for Cotton Crops

In these studies the water-table could not be maintained deeper than 9 ft. However, the observations lead to the conclusion that with water table beyond 15 ft. the crops yield will be optimum and its water wastage will be minimum. This will be the case irrespective of the nature of the soil. For a clay soil position of water-table up to 10 ft. is also not detrimental.

Sugar-cane

Studies on Sugar-cane variety L-54 were conducted in 8 lysimeters. Six of these had clay soil and the rest silty soil. The depth of water was maintained between 3 to 14 ft. in clay soil and between 8 to 11 ft. in silty soil. Observations were recorded for the full growth period. The sugar-cane was grown in March 1964. The observations were started to be recorded from 1st April, 1964 till it was cut on 12-2-65. During the growth of the plant, data with regards to surface irrigation, rainfall, run off, percolation and water requirements from soil as a result of sub-irrigation was recorded. Evaporation from free water surface was also measured. From this data the quantity of total evapo-transpiration was determined and other factors such as the ratio of evapo-transpiration to total evaporation, the ratio of sub-irrigation to evapo-transpiration and evaporation were worked out. The value of Blaney Criddle K was also determined. The percentage excess evapo-transpiration by assuming a certain value of the total requirement of the crops was worked out. All this information is given in Table No. 5.

The same crop was allowed to grow during the year 1965-66. Its observations were started from 14th February 1965 and continued till 9th January 1966. Similar observations as mentioned in Table No. 6 were carried out. The results collected during the year 1965-66 are shown in Table No. 6. This year was relatively dry and the total consumption of the crop was assumed equal to 52 inches and on this basis the various evaluations were worked out. The year 1964-65 was relatively wet year. In Figure 7 (*a*) and (*b*) the accumulative evapo-transpiration during the growth period for both the years is plotted. As the water-table rises, the

TABLE No. 5

Seasonal Evapo-transpiration Data by Sugar-cane L-54 from 1-4-64 *to* 12-2-65.
(All values are in inches).

Soil		Clay					Silty		
Lysimeter No.	..	1	4	5	2	6	3	8	9
Water-table in ft.	..	3.0	4.0	6.0	8.5	11.0	14.0	8.0	11.0
Surface Irrigation	..	16.5	16.5	17.77	17.60	17.60	16.5	16.5	16.5
Rainfall	..	28.84	28.84	28.84	28.84	28.84	28.84	28.84	28.84
Run off	..	3.0	3.1	2.8	4.5	5.1	4.1	3.1	5.2
Percolation	..	7.95	7.64	6.60	10.19	10.19	9.40	6.79	9.13
Sub-Irrigation	..	55.16	34.46	16.56	13.51	7.94	5.01	21.50	8.49
Evapo-transpiration	..	89.52	69.06	54.97	44.91	39.15	36.85	57.00	39.50
K Values	..	1.35	1.04	0.83	0.68	0.59	0.56	0.86	0.59
%Excess Evapo-transpiration *	..	142.0	86.5	49.0	21.4	5.9	0.80	54.06	6.8
Ratio of ET/EV	..	2.09	1.61	1.28	1.04	0.92	0.86	1.42	0.92
%of SI/ET	..	61.62	49.89	31.20	30.08	20.27	13.59	37.8	21.49
Ratio of SI (EV)	..	1.38	0.80	0.39	0.40	0.19	0.12	0.50	0.19

Total evaporation from free water surface, EV, during the period=43.0''
Total evapo-transpiration was assumed equal to 37 inches with water-table kept at 15 ft. below surface (due to excessive rainfall, the evapo-transpiration is taken as 37 inches for the year only).

K Values at 15.0 ft. water table=0.56 Blaney Criddle F= 66.4

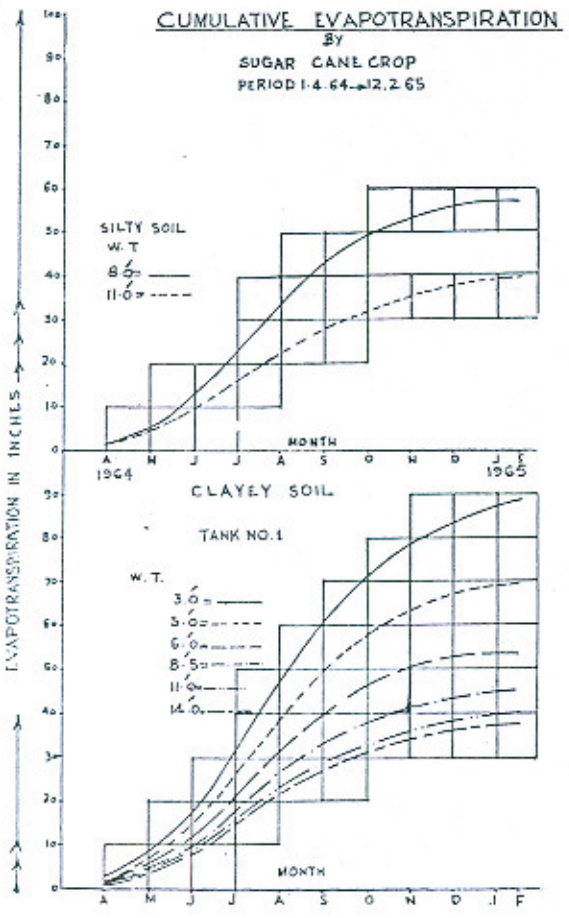
*% Excess Evapo-transpiration worked out assessing ET 37 inches at 15.0' table.

amount of evapo-transpiration increases. This is explained in Figure 8 where observations of both the years 1954-65 and 1965-66 are plotted. In Tables 5 and 6, already mentioned, the order of sub-irrigation and percolation is recorded. These values are plotted in Figure 9 which shows the order of the increases of the sub-irrigation as the water table rises. So is the case with the amount of percolation with varying position of water-table. It may be noted that at a depth of about 12 to 13 ft. the percolation and sub-irrigation becomes the same irrespective of the nature of the soil.

Yield of Sugar-Cane Crop with Depth of Water-table

At the time of harvesting the yield of sugar-cane, crop was estimated on the basis of the weight of the stripped plant. The number of plants in each lysimeter was counted and their weight was determined so as to work out an average weight of an individual plant. The yield of the crop with water table at 14 ft. was taken as standard, and the yield with water table at other depths was determined with respect to this level. The results of this measurement for both the years of studies 1964-65 and 1965-66 are shown

FIG. 7 (a)

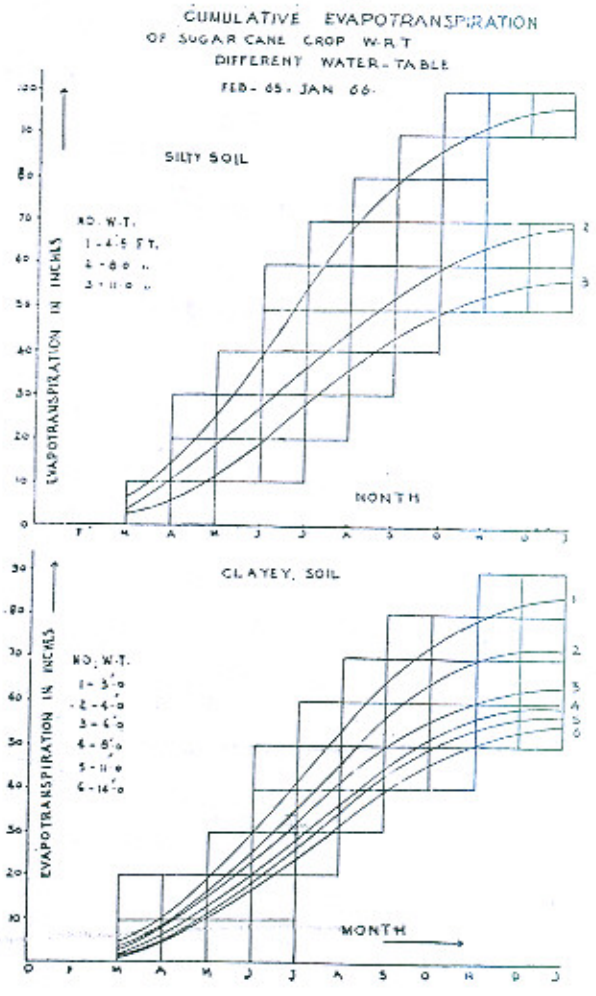


in Table No. 7 (*a*) and (*b*). The weight of each individual plant as well as the percentage compared with water-table at 14 ft. is shown. The yield during both the years is plotted in Figure 10. A study of the figure and the table shows that the yield of this crop increases with the rise of water-table. Even when the water-table is at 3 ft., there is no detrimental effect on the yield. Another point which needs consideration is that the yield has been more in case of silty soil as compared to the clayey one with water-table at the same depth.

Effect of High Water-table on the Quality of the Juice

This year an attempt was made to determine the quality of the juice from the plant taken from various lysimeters with different depths of water table. Electrical conductivity was also determined and percentage purity and juice percentage were recorded. The work was got done in the chemical laboratory of Rahwali Sugar Mill. The results of observations are given in Table No. 8 and plotted in Figures 11 (*a*), (*b*) and (*c*). A reference to these shows that in case of silty soil with water-table higher than 6 ft. the conductivity was slightly low. With water-table beyond 6 ft. it remains the same. As regards clay soil the conductivity remained practically the same at all depths rather it slightly decreased in case of silty soil. It can be concluded that due to the large

Fig. 7 (*b*)



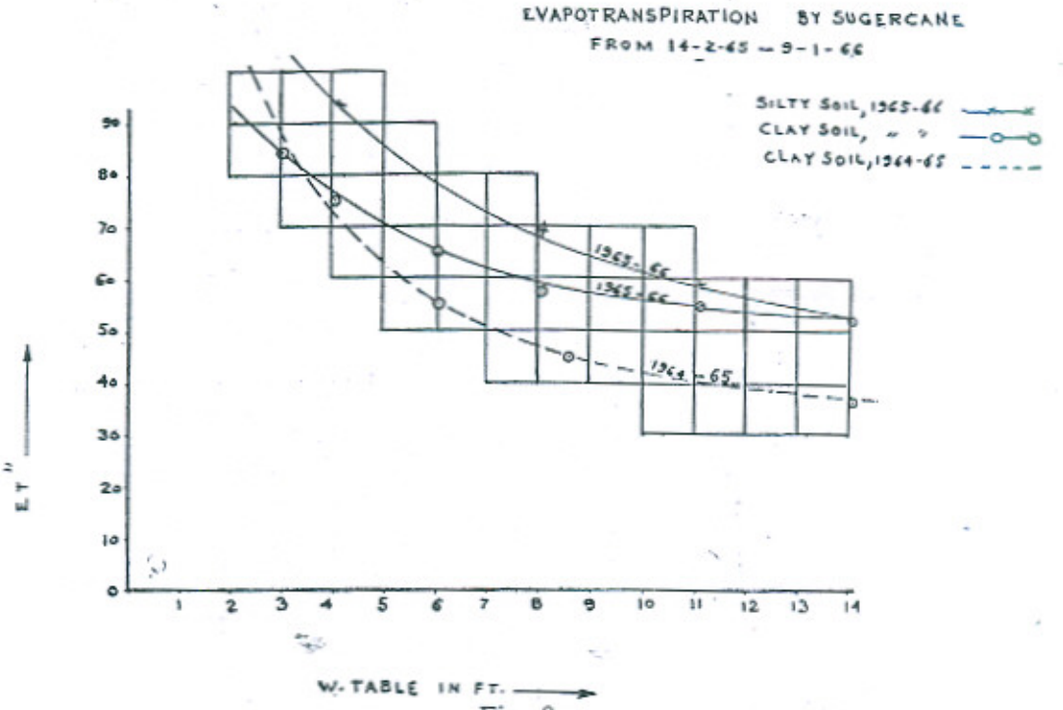

EVAPOTRANSPIRATION BY SUGERCANE
FROM 14-2-65 – 9-1-66
SILTY SOIL, 1965-66
CLAY SOIL, " "
CLAY SOIL, 1964-65
1965-66
1965-66
1964-65
E.T. "
W. TABLE IN FT.

Fig. 8

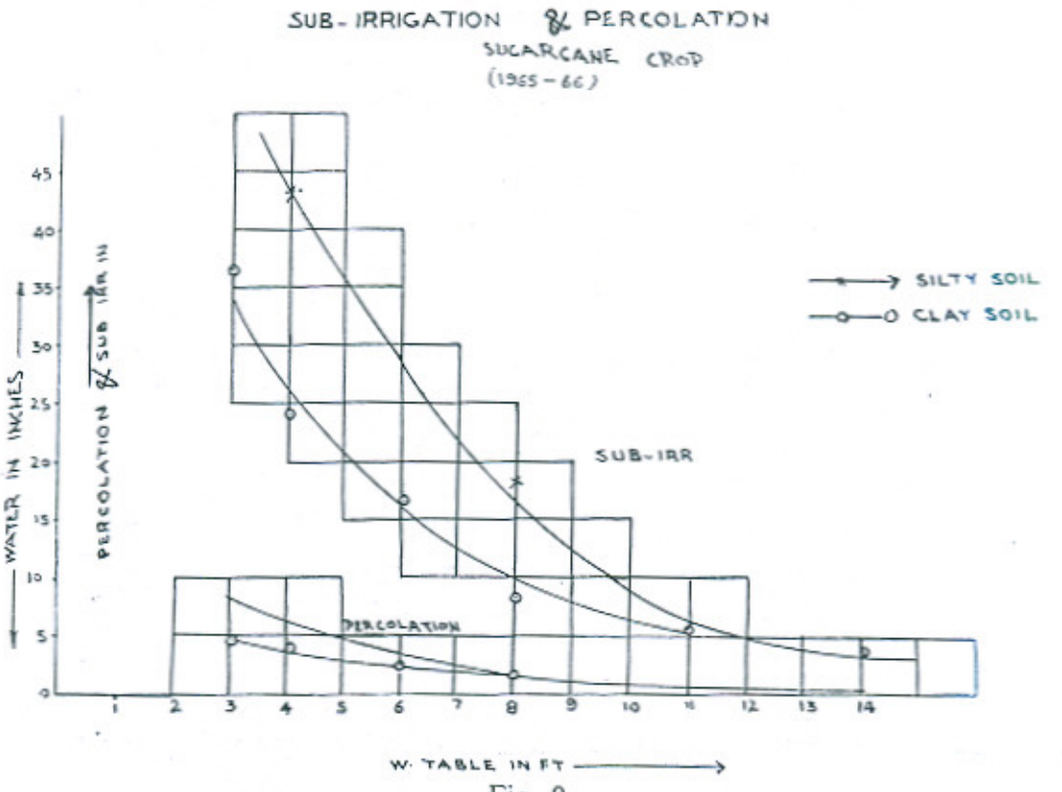

SUB-IRRIGATION & PERCOLATION
SUGARCANE CROP
(1965-66)
SILTY SOIL
CLAY SOIL
SUB-IRR
PERCOLATION
WATER IN INCHES
PERCOLATION & SUB IRR IN
W. TABLE IN FT

Fig. 9

amount of water transpired due to high water-table, there is some improvement in the conductivity.

As regards the percentage of juice in clay soil it remained practically the same irrespective of depth of the water-table. In case of silty soil there was slight increase in the percentage of the juice with rise of water-table.

As regards the purity of sugar-cane it remained practically the same with slight increase in purity with rise of water-table. It is thus concluded that a high water-table has no detrimental effect on the quality of sugar-cane or the juice, rather it was advantageous.

TABLE No. 6

Seasonal Evapo-transpiration Data for Sugar-cane L-54.

From 14-2-65 to 9-1-66. All values are in inches.

Soil	Clayey						Silty		
Lysimeter No.	1	4	5	2	6	3	7	8	9
Water-table (Ft.) ..	3.0	4.0	6.0	8.0	11.0	14.0	4.0	8.0	11.0
Surface Irrigation (Inch)	42.0	42.0	42.0	42.0	42.0	42.0	42.0	42.0	42.0
Rainfall ..	10.29	10.29	10.29	10.29	10.29	10.29	10.29	10.29	10.29
Sub-Irrigation (SI) ..	36.63	24.52	16.71	8.32	4.87	3.51	44.29	18.71	5.0
Percolation ..	4.52	4.03	2.53	2.02	1.88	0.52	6.51	2.12	0.55
Evapo-transpiration (ET)	84.60	72.78	66.47	58.59	55.29	55.28	90.07	68.88	56.74
%Excess evapo-transpiration* ..	62.7	40.0	27.83	12.67	6.33	6.33	73.21	32.46	9.12
Ratio of ET/EV ..	1.46	1.25	1.14	1.10	0.95	0.95	1.55	1.19	0.98
%of SI/ET ..	43.3	33.69	25.14	14.20	8.81	6.35	49.17	27.17	8.82
Ratio of SI/EV ..	0.63	0.42	0.29	0.15	0.08	0.06	0.76	0.32	0.09
K. Values ..	1.23	1.06	0.97	0.85	0.80	0.80	1.31	1.00	0.82

1. Assumed ET at 15 ft. W. T.=52 inches
2. Evaporation EV from F. W. Surface=58 inches
3. K. Values at the assumed ET with water-table at 15 ft.=0.756.
4. Total F= 68.8

*% Excess Evapo-transpiration worked out assuming ET 52 inches at 15.0 ft. table.

TABLE No. 7*a*

Yield of Sugar-cane with depth of Water-table.

(1964-65)

Soil	Clay						Silty	
Water-table in ft. ..	3.0	4.0	6.0	8.5	11	14	8	11
Yield in seers/ ..	53.5/	49/	42/	37/	33.8/	32/	40.5	33.8
Lbs. ..	114.1	104.5	89.6	78.9	72	68		
%Yield compared with W.T. at 14.0 ft. ..	167.2	153.1	131.3	115.6	105.5	100	..	..

TABLE No. 7*b*

Yield of Sugar-cane with depth of Water-table.

(1965-66).

Soil ..	Clayey						Silty		
Water-table in ft. ..	3	4	6	8	11	14	4.0	8.0	11.0
Weight in lbs. per lysimeter. ..	90	80	68	62	56.5	55.0	90	83.0	79.0
%Yield compared with 14.0 ft. water-table ..	163.6	145.6	123.7	112.8	100.2	100.0	145.2	134.0	127.4

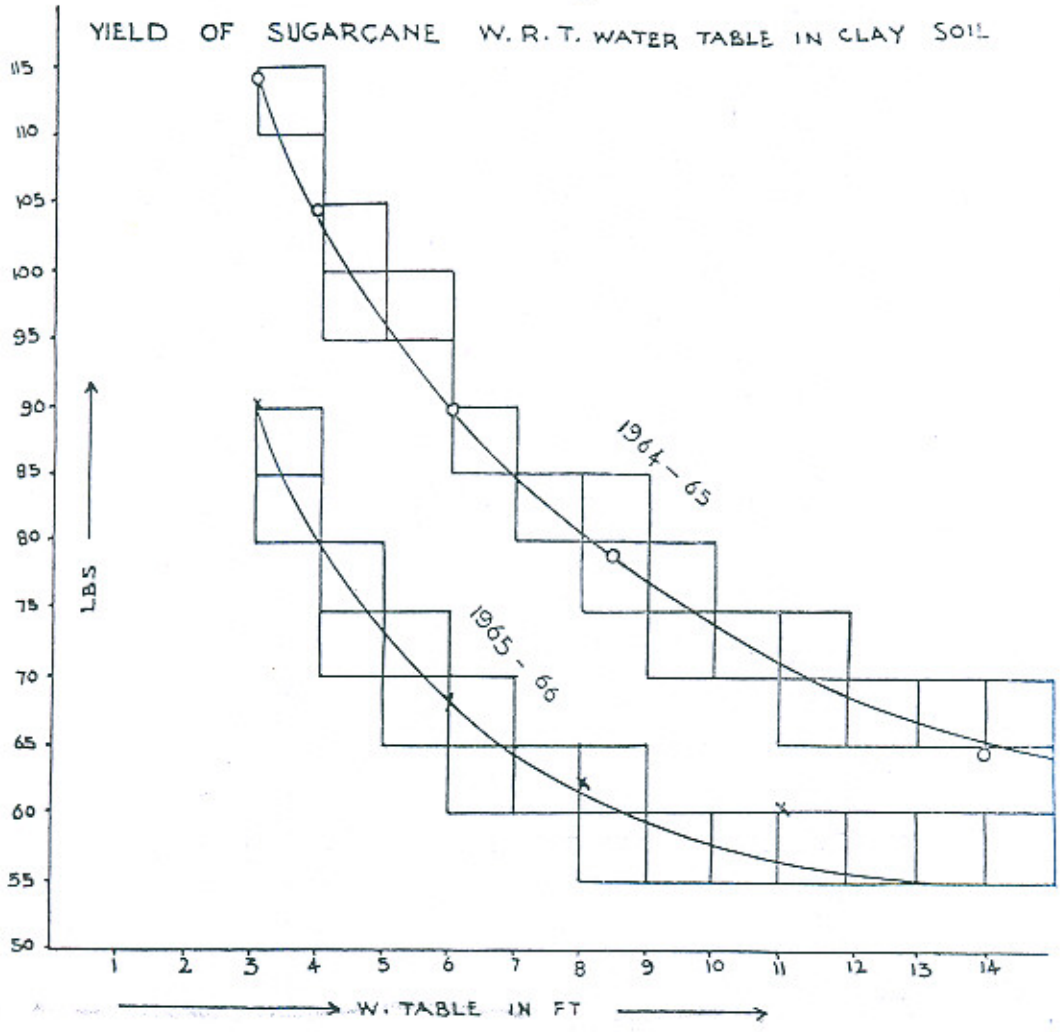


Fig. 10

Optimum Depth of Water-table for Sugar-Cane Crop

For this crop it is difficult to decide about the optimum depth of water-table. The higher is the water-table the more is the yield. The water wastage, however, increases sharply. There is, however, no deterioration in the quality of the sugar-cane. If we have to adopt an optimum depth of water-table, keeping in view the saving of water, it appears that depth of groundwater at 5 ft. for clay soil and 6 ft. with silty soil may be appropriate. This conclusion is based upon the data given in Table No. 9.

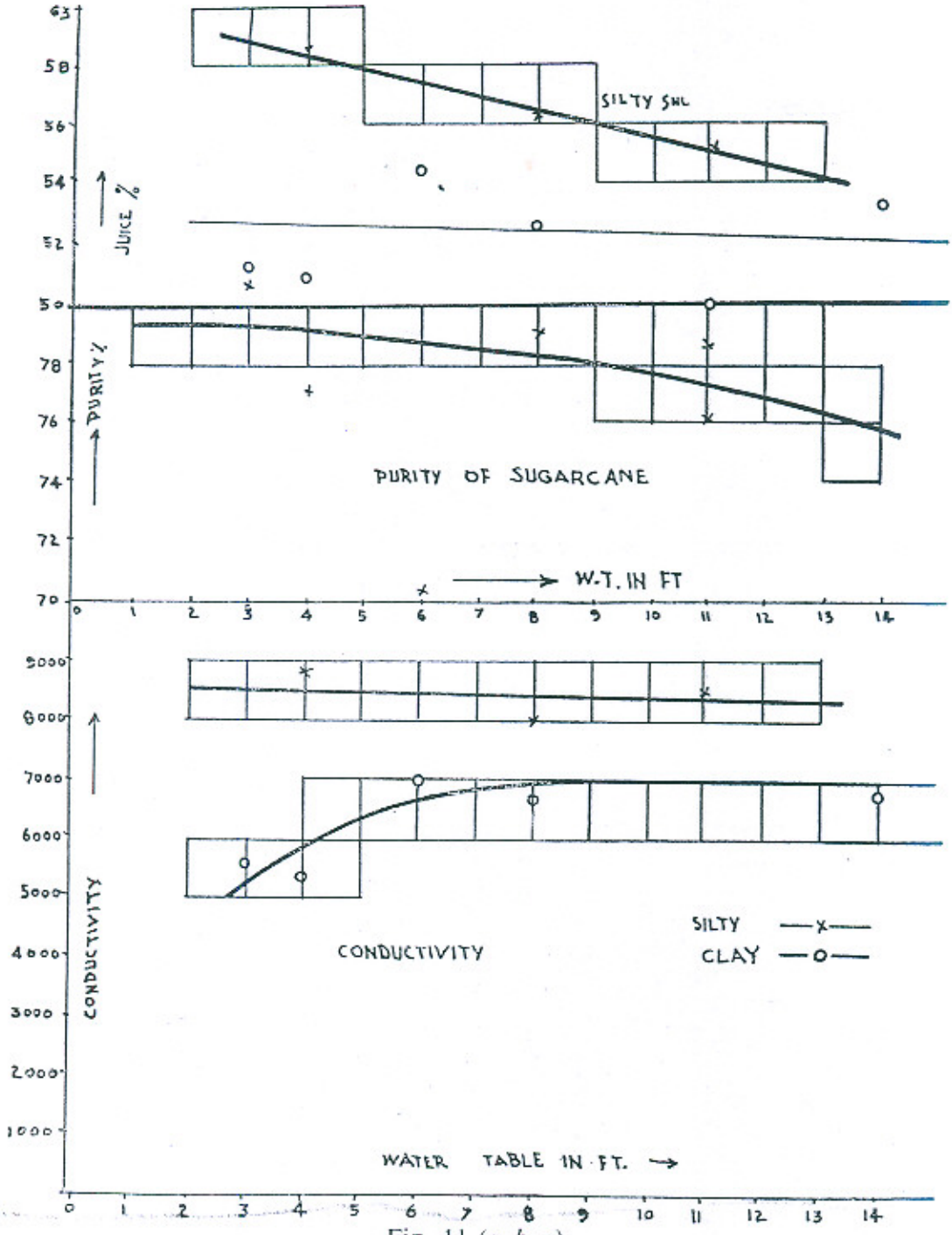


Fig. 11 (*a, b, c*)

TABLE No. 8

Sugar-cane Juice Analysis

Lysimeter No.	Soil	Water-table in ft.	Conductivity m. mhos/cm.		Percentage Purity		Juice Percentage	
			OBS.	Mean	OBS.	Mean	OBS.	Mean
1	Clayey	.. 3.0	5550	5300	80.46	79.2	51.28	52.8
4	do	.. 4.0	5400	5900	78.29	79.15	50.90	52.7
5	do	.. 6.0	7400	6650	70.39	78.8	54.34	52.6
2	do	.. 8.0	6700	6950	70.09	78.3	52.50	52.4
6	do	.. 11.0	7000	6950	76.14	77.3	50.0	52.3
3	do	.. 14.0	6750	6950	75.67	75.7	53.33	52.2
7	Silty	.. 4.0	8800	8500	77.02	79.15	58.52	58.4
8	do	.. 8.0	8000	8400	79.14	78.3	56.29	56.3
9	do	.. 11.0	8500	8375	78.67	77.3	55.17	55.2

Note: (*i*) Conductivity of the Sugar-cane juice at 3.0 ft. water-table is 24% low as compared at 14.0 ft. water-table.

(*ii*) Conductivity in case of silty soil is higher than clayey soil.

TABLE No. 9

Amount of water transpired and yield of Sugar-cane in clay soil compared with water-table at 14 ft.

Depth to W.T. (ft.)	3	4	6	8	11	14
% excess water transpired ..	142	86.5	49.0	21.4	5.9	0
% excess yield ..	67.2	53.0	31.0	15.0	5.0	0

Wheat Crop

Similar tests as described for cotton and sugar-cane were conducted on wheat crop during the years 1962-63, 1963-64, 1965-66. The investigations during the year 1965-66 were thorough. The data collected from these studies is shown in Table 10. The total water consumed by the crop is plotted in Figure 12. The total evapo-transpiration of the crop grown in clay soil to attain maturity under varying depth of water-table was determined and is plotted in Figure 13. This data was utilized to determine the percentage of excess water consumed under different depths of groundwater. These results are plotted in Figure 14.

Yield of wheat under various depths of groundwater

The yield of wheat crop was collected from each lysimeter. It was weighed and estimated as gram per sq. ft. of surface. This information is plotted in Figure 15 and given in Table 11.

TABLE No. 10

Studies on Wheat Crops

Evapo-transpiration, Sub-Irrigation with respect to Water-table and the Comparison with F.W.S. Evaporation.

Tank No. ..	6/1	1/5	7/1	2/5	8/1	3/5	9/1
Water-table in ft. ..	3	4	5	6	7	8	9
Evapo-transpiration in inches ..	34.9	30.3	26.7	23.8	21.2	18.75	17.0
%Excess Evapo-transpiration ..	168.5	133.1	105.4	83.1	63.1	44.23	30.8
Sub-Irrigation in inches ..	22.2	18.6	15.5	12.7	10.2	8.0	6.5
% $\frac{SI}{ET}$ ..	63.6	61.4	50.5	53.36	48.58	42.6	38.23
Ratio of $\frac{ET}{EV}$ ..	174	151	134	119	106	94	85
Ratio of SI/EV ..	1.11	0.93	0.78	0.64	0.51	0.40	0.33
K. Value ..	1.44	1.25	1.10	0.98	0.88	0.77	0.70

Evapo-transpiration assumed at 15' W. T. = 13.0 inches.
Sub-Irrigation assumed at 15' W. T. = 3.0 inches.
Lake Evaporation during growth period = 20.0 inches.
ET/Ev at 15' W. T. = 0.65 inches.
K. Value at 15' W. T. = 0.53 inches.

Note:—These values are by extrapolating Fig. 13 and 14 to 15 ft. depth.

TABLE No. 11

The Effect of Varying Quantities of Water on the Yield of Crops (Wheat). Average results for a period of 4 Years (1940-44) are given below:—

Treatment No.	Irrigation including Rauni Irrigation for sowing in inches	Rain in inches	Total water, Irrigation+ rain in inches	Yield per Acre in Mds.		
				Grain	Straw	Water Efficiency
1 ..	5.33	3.27	8.6	24.29	52.04	19.32
2 ..	8.33	3.27	11.6	27.27	56.42	10.05
3 ..	11.33	3.27	14.6	28.61	60.38	7.86
4 ..	14.33	3.27	17.6	30.47	6.81	6.88
5 ..	17.33	3.27	20.6	31.25	7.84	5.95
6 ..	20.33	3.27	23.6	30.98	7.29	4.9

The percentage fall in yield for different depths of water-table is worked out. The percentage excess water consumed as evapo-transpiration is recorded. The yield of the crop continued to fall with rise of water-table. Similar results have been recorded by Mohammad Hussain when he determined the yield with water-table kept at a depth of 0.8 inch, 2.5 ft. and 20 ft. (See Table 12).

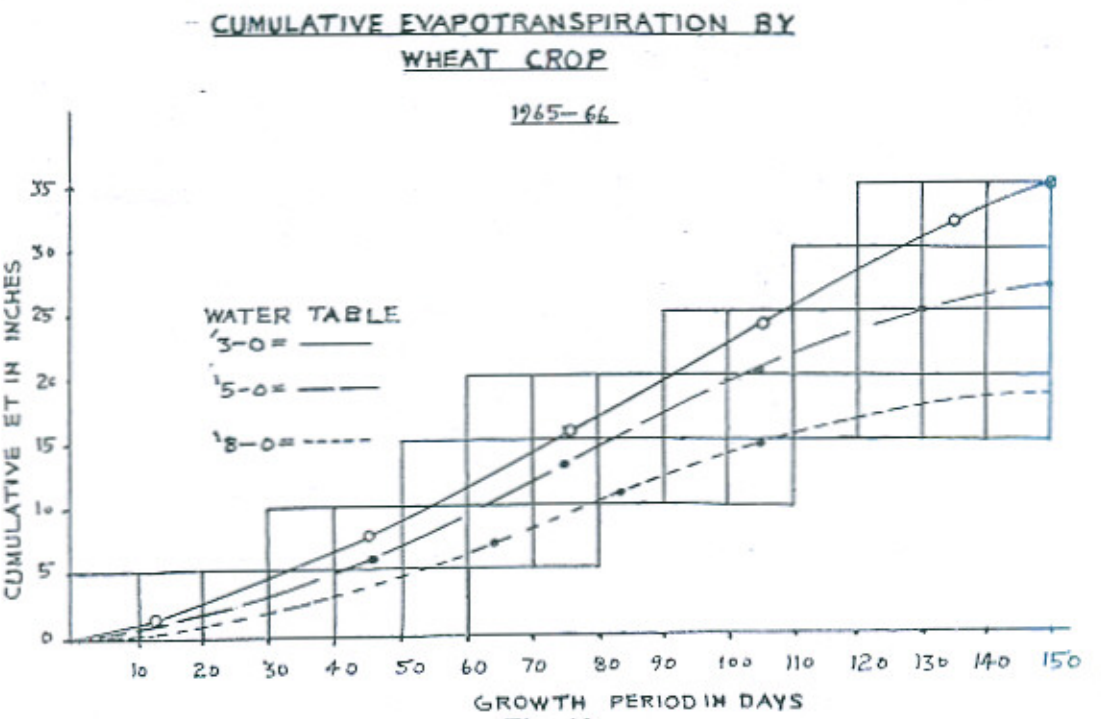


Fig. 12

TABLE No. 12

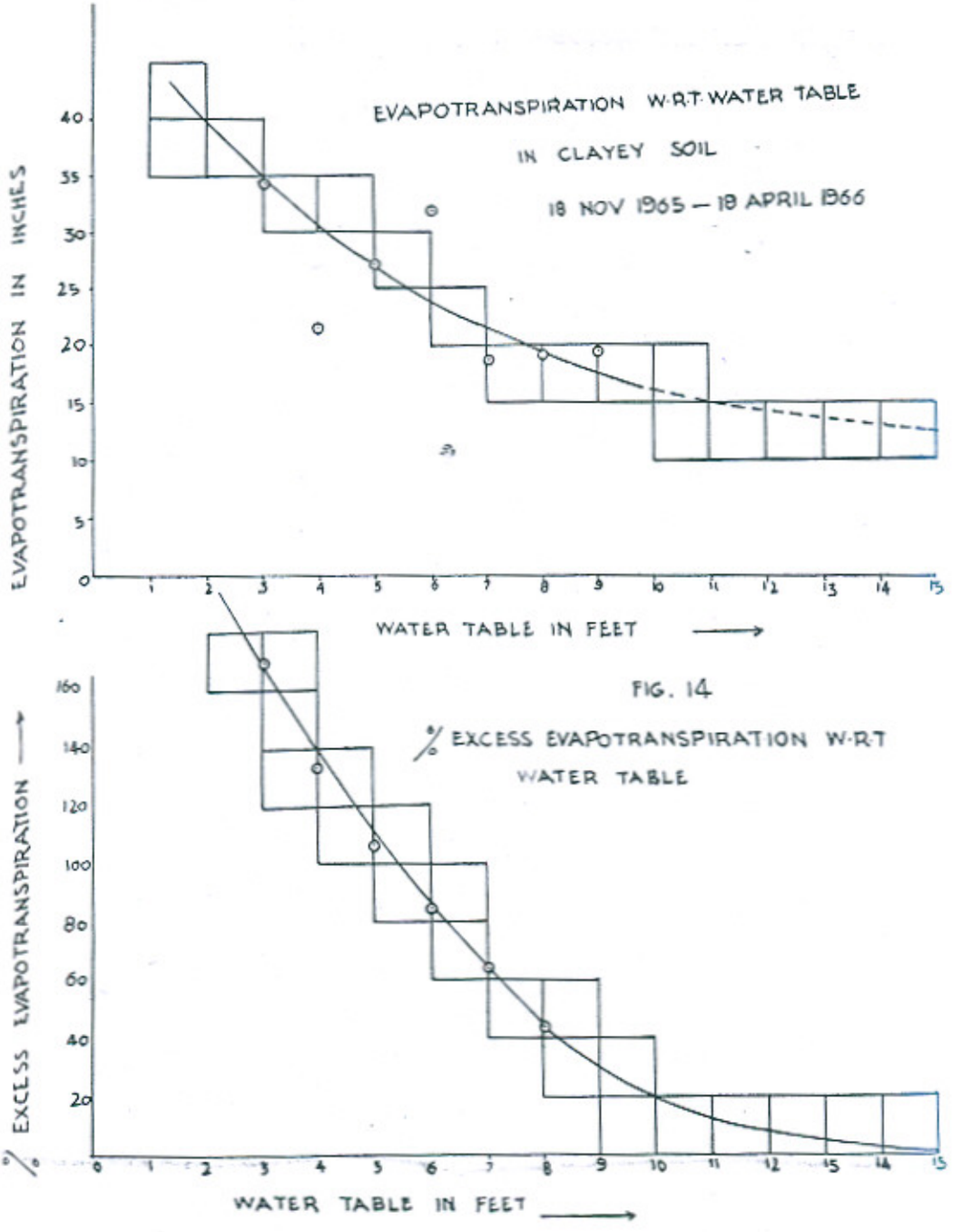
Relation of Wheat Yield to Sub-soil Water Level below Ground Surface.

Authority		Nazir Ahmad							Mohd Hussain		
Location	..	Niazbeg (Lahore)							Moghalpura (Lahore)		
Soil	..	Clay									
W. Table in ft.	..	3	4	5	6	7	8	9	8 (inches)	2.5	2.0
Yield gms/sq. ft.	..	17.5	22.5	27.0	30.5	32.5	33.5	34	3.80	9.23	16.94
% Reduction	..	48.5	33.8	20.6	10.2	4.4	1.4	..	77	45.6	..

Optimum depth of groundwater-table for wheat crop.

It was not possible to conduct the studies with water-table kept lower than 9 ft. When the evapo-transpiration against depth of water-table was extrapolated as shown in Fig. 13, it was found that at a depth of 15 ft. the excess water evapo-transpired was eliminated and the yield approached the normal order. It is thus concluded that 15 ft. depth of groundwater is appropriate for this crop.

Fig. 13



Evapo-transpiration of the crops compared with evaporation from free water surface.

During the course of these studies evaporation of water from lake type tank was continued to be observed. Daily evaporation from free water surface was thus estimated. In Tables No. 2, 5, 6 and 10, ratio of evapo-transpiration, ET, to evapo-ration from free water surface, EV, has been worked out. The depths of water-table when the evapo-transpiration started to increase more than evaporation from free water surface for the three crops were as under:—

Crop		Depth of water-table when the ratio ET/EV became more than one.
Cotton	..	upward of 9 ft.
Sugar-cane	..	upward of 10 ft.
Wheat	..	upward of 7.5 ft.

It is thus concluded that the presence of crop causes evapo-transpiration more than the evaporation from free water surface even when the water-table is fairly deep. This result is against the findings of Penmann?

Sub-Irrigation and Drainage Surplus

In Tables 2, 5, 6, and 10, the order of sub-irrigation and percolation which represents the drainage surplus has been worked out. In case of studies with cotton and sugar-cane crop, the surface irrigation was kept constant, but it was varied in case of wheat crop. It was noted that a substantial amount of water was drawn by the crop from the soil moisture. It is termed the sub-irrigation. With the rise of water-table the sub-irrigation increased considerably.

TABLE No. 13

Effect of Surface Irrigation on Sub-Irrigation, Drainage Surplus and Evapo-transpiration.

Year	Soil		Water-table in ft.	Surface Irriga-tion	% Ratio of SI/I	% Ratio of ET/I	% Ratio of DS/I
1962-63	Clayey	..	7.5	4''	246	346.0	Nil
1962-63	Silty	..	5.6	4''	396	497.0	Nil
1963-64	Clayey	..	5.0	17''	72	172.0	9.0
1963-64	Silty	..	5.0	17''	69	155.0	14.1
1963-64	Silty	..	6.0	17''	59	133.0	12.4
1965-66	Clayey	..	3.0	13''	171	268.5	3.1
1965-66	,,	..	4.0	13.0	143	233.1	2.3
1965-66	,,	..	5.0	13.0	119.2	205.4	1.55
1965-66	,,	..	6.0	13.0	97.7	183.1	1.10
1965-66	,,	..	7.0	13.0	78.6	163.1	0.70
1965-66	,,	..	8.0	13.0	61.5	144.2	0.48
1965-66	,,	..	9.0	13.0	50.0	130.8	0.23

SI = Sub-Irrigation in inches. ET = Evapo-transpiration in inches.
I = Sur-Irrigation in inches. DS = Drainage surplus in inches.

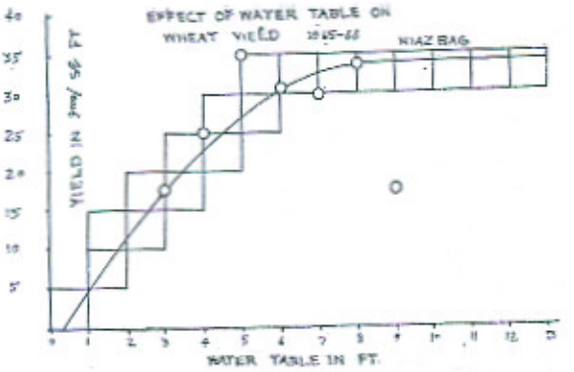


Fig. 15

The results of sub-irrigation as studied are very instructive. For the depth of water between 3 ft., 9 ft., 14 ft., its order was as under:—

Crop	Type of soil	Value of % $\frac{SI}{ET}$ for depths of water-table at		
		3 ft.	9 ft.	14 ft.
Cotton	Silty	63 ,,	37 ,,	..
Cotton	Clayey	49 ,,	28.5	..
Sugar-cane	,,	62 ,,	30 ,,	13.6 ft.
Sugar-cane	,,	43 ,,	14 ,,	6.4 ,,
Wheat	,,	64 ,,	42.6 ,,	..

The sub-irrigation both for cotton and wheat crop is higher as compared to sugar-cane at the same depth of water-table. It may be due to the structure of the roots system.

The drainage surplus was noted for all the three crops. There was no drainage in case of wheat when the surface irrigation was limited to only 4 inches. The increase of drainage with increase of irrigation in case of wheat crop is shown in Tables 13 and 14.

The last mentioned Table shows the excess of percolation with constant surface irrigation for varying position of water-table.

TABLE NO. 14

Percolation in Soil with different Water-table below Ground Surface and covered with Wheat Crop.

1965-66.

Water-table in ft.	Percolation in inches	% Excess percolation as compared at 10.0′
3	0.4	39
4	0.29	28
5	0.20	19
6	0.14	13
7	0.09	8
8	0.06	5
9	0.03	2
10	0.01	..

Value of Blaney Criddle Coefficients

In all the tables giving the observed data of three crops, the factor *k* has been worked out. It may be noted that the coefficient varied not only for each crop but with each depth of water-table and the nature of soil. The observed value of the coefficient approaches the calculated one on the basis of meteorological parameters. In this calculation no consideration is given to water-table and the nature of soil. The calculated values correspond to deep water-table.

General Conclusion

These studies have led to a better understanding of water utilization by the three crops. It gives the idea of the optimum depth of water-table when the wastage of water will be avoided and crop yield will be optimum. An idea of the use of soil moisture by the crop and the amount of drainage caused by each crop is also put forth. These studies can be utilized to exactly estimate the water utilization by the crops under different physical conditions.

Corrosion of Reinforcing Bars in Concrete

By JOHN D. MOZER,
ALBERT C. BIANCHINI, and
CLYDE E. KESLER

Although corrosion is an important aspect to be considered in the design of reinforced concrete structures, corrosion in service is not a common problem in the great majority of reinforced concrete applications. It is only in a limited number of cases, which usually have involved poor workmanship, improper construction practices, and inadequate design procedures as well as exposure to aggressive environments, that corrosion has been a problem.

The purpose of the paper is to present information on the nature and mechanics of corrosion of steel, information on the factors associated with the concrete and steel which will influence corrosion, and to discuss preventative methods to inhibit corrosion. The paper is concerned only with reinforcing bars. The paper has been written for the engineer and not the scientist.

NATURE AND MECHANICS OF CORROSION OF STEEL

The current state of knowledge on the subject of corrosion has evolved rapidly over the past 20 years, however, there are still many aspects of the problem which are not fully understood. The corrosion mechanism, even when restricted to a single system, is extremely complex. This becomes evident when it is realized that the many factors which may influence the various reactions are not necessarily independent. Consequently, it comes as no surprise to find different theories that attempt to explain the corrosion phenomenon and that often conflict with one another. No attempt will be made to enumerate all the various theories that have been presented by authorities in the field. However, there are certain facts pertaining to corrosion which have been well established by means of considerable study and research. The purpose of this section will be to incorporate these recognized facts into a discussion on the corrosion of reinforcement.

Reproduced from Journal of the American Concrete Institute, August 1965 issue.

Mechanism of corrosion

Corrosion may be defined as the deterioration or destruction of a metal due to chemical interaction with its environment. The reaction may be brought about by direct chemical attack, but more commonly, it is electrochemical in nature. According to Evans, corrosion may be generally considered as any transformation whereby the metal goes from the elementary condition to the combined condition. In this aspect, it may be viewed as the opposite of the chemical process in which a metal is refined from its ore. No matter how the reaction is defined, it is a function of the metal, the chemical environment, and the mechanical and physical conditions existing in the system under consideration. By far the most common types of corrosive attack, including that on reinforcement embedded in concrete, are those produced by electrochemical driving forces.

A review of the basic galvanic cell will aid in developing an understanding of the electrochemical reaction on reinforcement in concrete. A galvanic cell is set up when two dissimilar electrodes, separated by an electrolyte, are electrically connected by a conductor. Perhaps the simplest type of galvanic cell is the flashlight battery. Zinc, used in the battery case, serves as one electrode anode and the center carbon rod cathode serves as the other. The space between the electrodes is filled with an electrolyte which is an aqueous paste material.

Zinc enters into solution in the form of metallic ions and eventually is deteriorated by continuous ionic flow. Hydrogen ions migrate through the electrolyte to the carbon rod where they are plated out as hydrogen gas.

A galvanic cell also exists when two similar metals are separated by dissimilar electrolytes.

The actual mechanism involved when reinforcement in concrete is subject to corrosive attack is similar to these basic galvanic cells, but much more complicated. Consequently, a more detailed discussion of the general electrochemical mechanism will ensue to enable a more complete understanding of the corrosion phenomenon.

The electrochemical mechanism may be considered as providing an alternate path for the chemical reaction. For this to take place, there are three conditions which must exist: (*a*) there must be a potential difference between two metallic areas, (*b*) there must be a conduction path and (*c*) there must be appropriate electrode reactions taking place. A difference in potential may arise from almost any conceivable heterogeneity of the system, that is, any assymmetry of the metal, or the environment, or both. The various effects of such assymmetries will be discussed in the section dealing with the influence of factors associated with the metal and the environment.

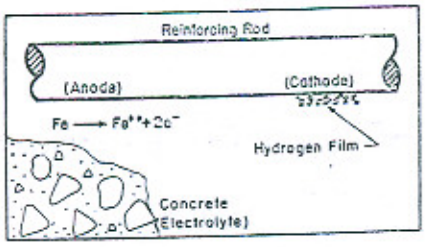
Typical chemical reactions

The tendency of a metal to oxidize to a metal ion in an aqueous solution of normal ionic activity at standard temperature is given in the electromotive force series. A normal hydrogen electrode is usually selected as an arbitrary reference. Any metal high in this series will have a greater tendency to corrode. Consequently, iron which is relatively high in the electromotive series will have a substantial tendency to enter into solution. As previously mentioned, the area where the metal ions go into solution becomes the anodic region. The ionization of the metal at the anode is often referred to as the first

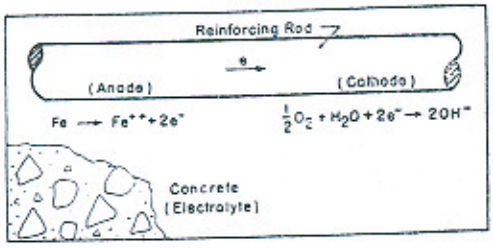
or primary stage of the corrosion reaction and may be represented by the following equation:

(Anodic reaction)

$$Fe \rightarrow Fe^{++} + 2e^{-} \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$



(*a*) Primary Reaction—Formation of Hydrogen Film at the Cathode which inhibits Subsequent Reaction.



(b) Secondary Reactions — Breakdown of the Hydrogen Film thus allowing the Corrosion Process to continue.

Fig. 1—Typical chemical reactions

The anodic region of the metal now has an excess of electrons as indicated by this equation. To maintain equilibrium of electric charges an equivalent quantity of hydrogen is plated out at adjacent surfaces of the metal. This results in a thin invisible film of hydrogen around the cathode and this protective film inhibits further progress of the reaction as shown in Fig. 1a. Consequently, any subsequent reaction will cease unless the hydrogen film is removed in some manner.

The destruction of the film may take place in one of two ways: (*a*) oxygen depolarization at the cathode, and (*b*) hydrogen evolved as a gas, as shown in Fig. 1b.

(Cathodic reactions)

$$^{1}/_{2}O_2 + H_2O + 2e^{-} \rightarrow 2OH^{-} \quad \ldots\ldots\ldots (2a)$$

$$H_2O \rightleftarrows 2H^{+} + O'' \quad \ldots\ldots\ldots (2b)$$

These cathodic reactions which are often called the secondary reactions are the controlling reactions on the rate of corrosion for iron or structural steels. Therefore, any environmental condition which influences these reactions will likewise influence the rate of corrosion. Corrosion processes characterized by the cathodic depolarization by oxygen [Reaction (2a)] are probably of widest importance. Since this reaction is dependent on the concentration of dissolved oxygen next to the metal, it is influenced by the degree of aeration, temperature, salt concentration, etc. Reaction (2b) generally is not characteristic of the corrosion of steel in concrete; however, it should be mentioned that such reactions will take place in either acid solutions or concentrated alkaline solutions.

The secondary reactions permit the primary reaction to proceed with the accumulation in the solution of ferrous ions, Fe^{++}, which in the presence of water and oxygen are oxidized and precipitated as rust. Two states of oxidation may exist depending mainly on the availability of oxygen. The first state, ferrous hydroxide, is more soluble than the second, hydrated ferric hydroxide. The first is usually formed directly at the metal surface and is converted to the latter at a little distance away from the surface where it is in contact with more oxygen as shown in Fig. 2. If the supply of oxygen is limited, the product may be green hydrated magnetite or black anhydrous magnetite, but these products are relatively uncommon. In

between the two layers of ferrous hydroxide and ferric hydroxide there may exist combinations of the two compounds.

The structure and composition of the rust varies considerably with the conditions prevailing during its formation and the structure plays an important role in the

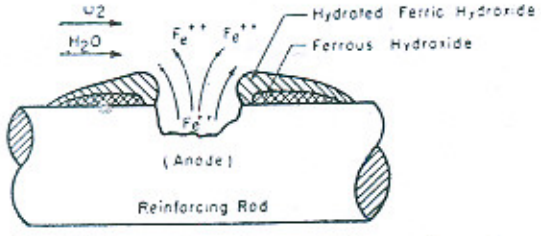


Fig. 2—Formation of rust at the anodic region

subsequent corrosion process. If the rust layer is hard, dry, and fairly adherent to the metal surface, then it may retard corrosion by forming a protective coating. On the other hand, if the layer is spongy and readily detachable, it will absorb oxygen and moisture from the surrounding media and consequently will add to further activity.

If a process comprises two or more reactions, as in the case of electrochemical corrosion, then the rate of the process is determined by the rate of the slowest of these reactions under the particular conditions. In most cases, the primary reaction is much faster than the secondary reactions and since the dominant influence on the latter is the oxygen concentration of the media, then it is likewise the dominant influence on the rate of the overall corrosion process. However, there are other factors which may also enter the picture. If the cathode is large and consequently exposed to a greater amount of oxygen, then the cell current may be quite strong in relation to the size of the anode. This intensifies the attack and results in a greater rate of penetration at the anodic region.

It should be pointed out that the magnitude of the electrochemical potential determines the tendency of the reaction to proceed, whereas the rate of corrosion is determined mainly by resistance to the continued process set up by certain of the corrosion by-products. There are three conditions which may exist that will tend to resist the continued reaction (2): (*a*) the supply of electrons at the metal surface takes place much more rapidly than the supply of retractable particles from the media, (*b*) the corrosion product serves as a protective coating as previously mentioned and retards the rate of corrosion, and (*c*) the discharge reaction is retarded even though there are sufficient electrons and solution particles available at the metal-solution interface. This third condition is a general problem of electrode kinetics which is still not perfectly understood. When any of the above conditions exist, the electrode potential changes and the electrode is said to be polarized. If the slope of either the cathode or anode polarization curve is increased, the local cell current is reduced and consequently the corrosion rate is reduced. Conversely, a reduction of the slope increases the corrosion rate. Such reduction in slope of the polarization curve is termed "depolarization" and may be brought about by increasing the electrode area or by introducing chemicals which aid the electrode reaction.

CORROSION OF STEEL REINFORCEMENT EMBEDDED IN CONCRETE

Even in the simplest cases, the corrosion process is extremely complicated and is greatly and diversely influenced by numerous factors, both external and internal. Often it is found that the effect of a single factor may not be difficult to determine, but it is a

different matter when having to estimate the net effect of several factors working in conjunction with each other. Therefore, the discussion to follow will consist mainly of a study of each of the variables and their singular effect on the corrosion reaction.

However, this is not the only scheme that may be used. Speller, for instance, separates the factors which govern this tendency of the corrosion reaction to proceed from those which influence the rate of reaction.

Factors associated with the steel

If the metal surface consists of any heterogeneities, there will be differences of effective potential thus establishing probable corrosion cells. Nonhomogeneities may be caused by differences of chemical composition over the surface, discontinuous surface layers, or differences in texture. Differences in chemical composition may be due to any heterogeneity characterized by impurities, grain boundaries, or a variation in corrosion resistance of the microstructure. There is always some characteristic of the metal structure, some degree of segregation, or some presence of impurities which is sufficient to produce varying potentials. These factors inherent in the metal tend to increase the probability of corrosion and, additionally, may tend to localize the action. From the standpoint of *total* corrosion, however, these factors are not as important as the external conditions which may exist.

Another source of differences in potential is due to stress either static or cyclic, in the reinforcement. Borgmann views this as simply a modification of the bimetallic couple problem; the crystalline structure in the strained areas having a somewhat different configuration from that in the unstrained areas. The rearrangement is such that the strained regions become negative or anodic to the unstrained regions thereby setting up electrochemical couples. Generally, it is tension stresses which cause trouble in corrosion. Tension stresses exert a force on the grain boundaries at the metal surface and if corrosion sets in along these boundaries, the stresses will open the grooves produced between the grains. This effect exposes the boundaries to further corrosive attack and at the same time creates stress concentrations which disrupt protective surface films and predisposes the metal to continued attack.

In the case of static stresses, the corrosion is usually intergranular. In the case of cyclic stresses, the attack is generally transgranular and tends to follow those planes so situated that the resolved shear stresses are maximum. If the range of alternating stresses exceeds a certain value defined as the "fatigue limit," any crack originating at the metal surface will propagate through the cross section until fracture occurs. Below the fatigue limit failure will never occur, no matter how many cycles are applied, provided that corrosive influences are absent. If corrosive conditions are present the metal structure, being unstable, will deteriorate at the crack boundaries and the crack will extend no matter how low the stress range.[1]

The stresses in bars for ordinary reinforced concrete are generally lower than necessary to cause this type of corrosion and this mechanism is not believed to be of great importance.

Another factor inherent in the metal is the tendency of the metal to form a protective film. This is commonly referred to as the passivity of the metal. Passivity is the ability of a metal to become abnormally inactive in a given environment; in other words, a passivated metal is characterized by a more

noble potential under certain environmental conditions. It should be mentioned that although passivity is due to a protective film on the metal surface, it is still associated with the properties of the metal itself. The passivity of a metal is affected by environmental factors—these factors dictating the duration of the transitory passive state. It follows, then, that the behavior of a passivated metal is controlled by either physical or chemical changes in the surface film and these changes are generally brought about by various environmental factors.

Various theories of passivity have been suggested over the past years. A fairly thorough discussion of these theories is presented by Pollitt.

Factors associated with the concrete

In the basic concrete-steel system, electrochemical cells are in most cases set up by heterogeneities of the concrete media. Two types of corrosion cells may exist depending on the prevailing conditions. The first type, often called the *microcell*, is characterized by microscopic distances separating the anodic and cathodic regions. Such cells are set up when moisture containing oxygen, carbon dioxide, and chloride salts penetrates the concrete surface and migrates to the reinforcement. Under these conditions the so-called "microenvironment" is no longer inhibitive of corrosive action and numerous microcells will operate. Most common among this type are the mill scale cell and the differential aeration cell. The second type commonly known as the *macrocell* operates when the concrete permeability varies from place to place on a macroscale. Reaction variables which influence macrocell corrosion are the moisture content, chloride content, pH at the concrete-steel interface, and the amount of available oxygen. The basic galvanic cells described earlier fall in the macrocell class and are the easiest to visualize.

When moisture is present the concrete medium becomes an electrolyte containing mainly calcium hydroxide. The various ions present which could influence the corrosion reactions are hydroxyl, calcium, sodium, potassium, carbonate and sulfate ions.

Effect of pH—Speller simply states that corrosion in acid solutions tends to be more rapid than in neutral solutions (pH=7) and the latter is more rapid than in alkaline solutions (pH>7). It follows then, that the influence of alkalies on the corrosion reaction is inhibitive. Metzger has shown with the use of the Pourbaix diagram that corrosion will occur for Fe—H_2O at 25°C for pH values between 0 and 10 and for pH values greater than 12. These values are dependent on the electrical potential.

It has been shown by Mayne and Menter that steel becomes passive in sodium and calcium hydroxide solutions due to the formation of an impervious layer of ferric products on the steel surface. Weak areas in the initial rust layer are first repaired by the formation of ferrous hydroxide which then reacts with oxygen to form Fe_3O_4 (magnetite) and Fe_2O_3 (ferric oxide). Later repair may occur by direct electrochemical production of ferric oxide. If, for some reason, the hydroxyl ion concentration is reduced, the protective layer would be disrupted and corrosion would proceed.

Influence of oxygen (differential aeration)—Oxygen may be considered not only as an essential factor to corrosion, but as the one primarily responsible for the progress and rate of corrosion. Oxygen acts as a depolarizer at the cathode as indicated by Reaction (2a), and consequently tends to

increase the velocity of corrosion. Dissolvd oxygen alone will accelerate corrosion in acid, neutral, or slightly alkaline electroytes. All things being equal, the rate of corrosion in a neutral solution is almost directly proportional to the oxygen concentration. The influence of dissolved oxygen on the corrosion process is illustrated by the qualitative curves shown in Fig. 3. These curves, obtained from experiments by Mayne, Menter, and Pryor are representative of iron specimens immersed in sodium hydroxide solutions. Curve I represents the corrosion rate in a de-aerated solution; the sharp break in the curve takes place at time X when air was admitted into the solution. Curve II represents the corrosion rate in a similar solution except that the system was in contact with air throughout the entire experiment.

The chief action of oxygen is as a depolarizor at the cathode, but at the anode it may lead to the formation of protective layers. This is specially important in the case of steel where the formation of insoluble ferric hydrates influences the rate and probability

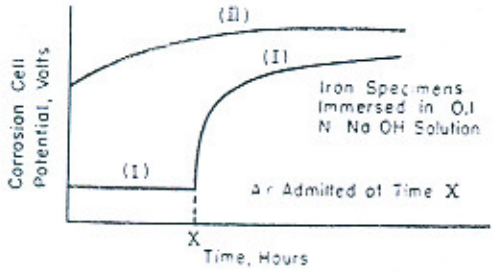


Fig. 3—Influence of dissolved oxygen

of corrosion. Thus, oxygen may play a dual role: as a depolarizing agent, it tends to enhance corrosion: on the other hand it may produce protective layers over the anodic regions prohibiting further reaction. It has been shown that as the oxygen availability is increased, the probability of corrosion is decreased, whereas the intensity of arttack is increased.

Differential aeration, that is, the unequal distribution of oxygen over the steel surface, will set up anodic and cathodic regions. Regions of the metal least accessible to oxygen become anodic, and regions readily accessible to oxygen becomes cathodic. Thus, the presence of oxygen in varying concentrations along the reinforcement will tend to increase the probability of corrosion. The influence of differential aeration emphasizes the deleterious effects of cracking and of porous concrete; two conditions which allow the penetration of oxygen to local areas of the reinforcement.

Influence of moisture (differential moisture contents)—As mentioned previously, the corrosion reactions will occur only if moisture is present. Therefore all corrosive factors become ineffective in the absence of moisture. Additionally, moisture penetration is the means whereby any exterior substances such as chloride salts, carbon dioxide, and dissolved oxygen may gain access to the reinforcement. Corrosion macrocells may be set up by differential moisture contents along the reinforcement—the regions having the greatest moisture content being anodic.

Influence of chloride ion concentration—The influence of chloride ions is not as readily predictable as the influence of pH. However, it is well known that the presence of salts may be expected to increase the corrosion rate if only because it is conducive to ionic activity. Salts, derived from the combination of strong acids and weak bases, will hydrolyze in a solution giving a definite concentration of hydrogen ions.

However, the presence of salts provides two opposing effects: (*a*) it increases the conductivity of the electrolyte thus raising

the corrosion rate, and (*b*) at high concentrations it diminishes the solubility of oxygen and thereby may lower the corrosion rate. Consequently, as the salt concentration of the electrolyte is increased, a maximum corrosion rate would be expected as shown in Fig. 4. Thus, the influence of salts depends chiefly on their concentrations.

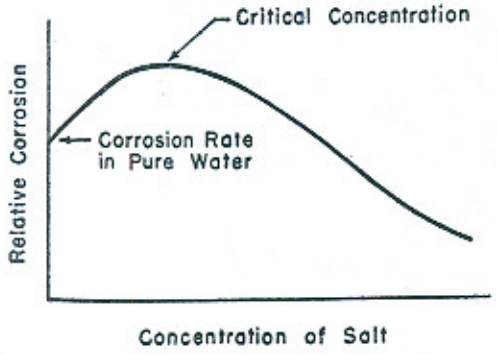


Fig. 4—Influence of salt concentration on the rate of corrosion

The inhibiting influence of salts present, in high concentrations, is not entirely due to the subsequent decrease in oxygen solubility. Experiments have shown that the reduction of the corrosion rate in saline solutions is not proportional to the reduction of oxygen solubility. It is, in fact, much more rapid as shown in Fig. 5. It is believed that the precipitating action of the negative salt radicals comes into play when the critical concentration is exceeded, and the corrosion rate is thereby retarded. Further increases in salt concentration will continue to retard corrosion and a concentration may be reached at which complete prohibition occurs.

Therefore, the effect exhibited by the various salts depends not only on their concentration, but also by their negative ion valencies which reflect their precipitating power. The relative precipitating powers of various negative ions have been investigated and found to have the following ratios.

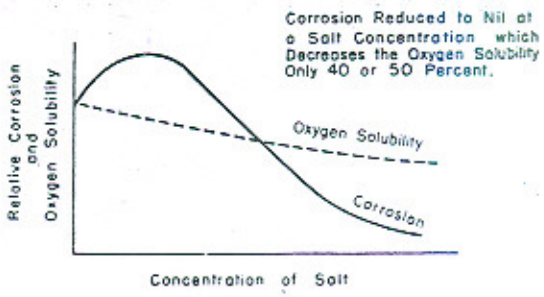


Fig. 5—Effect of salt concentration on corrosion rate and oxygen solubility

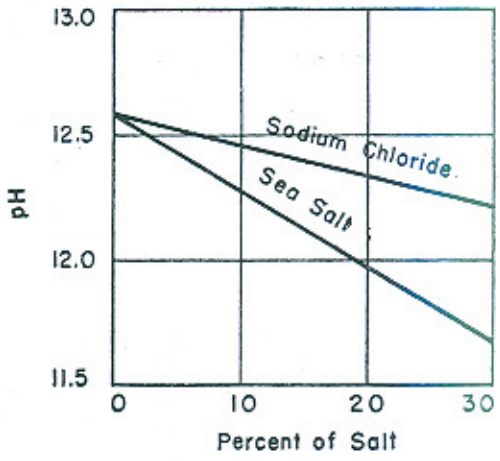


Fig. 6—Effect of salt concentration on pH values

Chromates and bichromates	1000
Sulfates	670
Chlorides and nitrates	3

Since chlorides exhibit a low precipitating power as shown in the above table, a relatively high concentration of such salts is required for corrosion to be retarded. Therefore, the influence of sodium chloride and other such salts is usually to enhance the corrosion process unless they are present in abnormally high concentrations.

To ascertain the effect of sodium chloride and sea salts on the pH value of an alkaline media, Shalon and Raphael conducted a series of tests in which steel bars were immersed in calcium hydroxide solutions of various concentrations. The pH values were reduced proportionally with salt concentration as shown in Fig. 6. A schematic

presentation of the effect of both salt concentration and pH in a $Ca(OH)_2$ solution is illustrated in Fig. 7 also taken from Shalon and Raphael's report. As the concentration

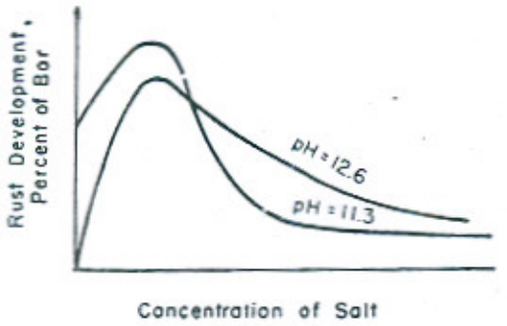


Fig. 7—Schematic presentation of the effect of salt concentration and pH in $Ca(OH)_2$ solution.

of salt increases, the protection afforded by the higher alkaline solution (pH = 12.6) is reduced and rust development takes place at an increased rate. Past the critical salt concentration, the inhibitive influence of the negative salt ions comes into play. Therefore, when water containing soluble chloride salts penetrates the concrete, the safety margin derived from the alkalinity of the concrete is markedly reduced. The investigators concluded that "the alkalinity of air-exposed concrete penetrated by saline water is insufficient for complete inhibition of corrosion of the reinforcement."

Different salt concentrations at various regions of the reinforcement tend to produce corrosion microcells and thus increases the corrosion probability. Differential salt concentrations, therefore, have an effect similar to that of differential aeration and differential moisture contents.

Influence of carbonation—If carbon dioxide is absorbed into the concrete, the calcium hydroxide will be converted to calcium carbonate thereby reducing the pH and, consequently, the protective value of the concrete. Values of pH of 10 and lower may result, especially if sulfur dioxide is also present. Enough evidence has been accumulated, however, to prove that in a concrete of high quality (low permeability) atmospheric carbonation is not likely to proceed beyond a few millimeters, thus the pH in the region of the reinforcement is not affected. Carbonation also tends to increase the shrinkage of concrete and thus promotes the development of cracks. Shrinkage cracks will increase the porosity of the concrete hence allowing the penetration of moisture and other external chemicals which may promote corrosion.

Quality of concrete—The permeability of concrete is probably the most important single factor affecting the corrosion of the reinforcement. Concrete of high permeability will have a high electrical conductivity and will allow the penetration of deleterious substances to the reinforcement. Concrete permeability depends on numerous factors, some of which are: water-cement ratio, richness of mix, aggregate size, aggregate grading, methods of compaction, curing etc. A detailed discussion of the more significant factors which govern concrete permeability is presented later.

Low quality concrete is also characterized by voids of appreciable size adjacent to the reinforcement. High moisture contents may exist in such voids thereby setting up macrocells perpetuating rapid corrosive attack.

Influence of storing conditions—Corrosion has been found to be greater when concrete is stored under moist conditions than when stored under dry conditions. If the atmosphere in the region of the concrete member has a relative humidity of 50 per cent or less, corrosive action may be reduced to zero. Likewise, structures permanently immersed in water will exhibit little or no corrosion

of the reinforcement. The concrete of submerged structures generally maintains a high pH value and a uniform salt concentration thus reducing the occurrence of corrosion cells.[11] Probably the main reason why submerged members are protected, however, is that oxygen starvation takes place, *i.e.*, no air is available at the concrete surface and thus cannot penetrate to the reinforcement.

Effect of temperature—The corrosion of concrete reinforcement is not greatly influenced by temperature (either curing temperatures or environmental temperature gradients); therefore, this factor will only be briefly discussed. A rise in temperature may result in a two-fold effect: (*a*) the reaction rates are generally increased and (*b*) the oxygen solubility is decreased, hence, reducing the rate of corrosion. An extreme rise in temperature, however, will accentuate the effects of the other reaction variables previously mentioned and may bring into action factors which otherwise would be negligible.

Effects of corrosion

In most cases, the corrosion rate is extremely slow and the normal life span of a structure is not largely affected. However, if the external and internal conditions are such that a corrosive environment exists, a destructive action may take place at an increased rate and create serious problems.

Intensified corrosive action produces deep pitting and a severe loss of cross section of the reinforcement. This is particularly serious if the reinforcement is subjected to high stresses as in the case of structures carrying large loads. A combination of high stress and intense corrosion will produce stress concentrations that may result in rupture of the reinforcement.

Corrosion cracking is another problem which may occur under intensified corrosive attack on the reinforcement. Severe corrosion of the reinforcement usually results in cracking of the concrete in a direction parallel to that of the reinforcement. These cracks result from internal pressures created by the oxide rust products which occupy a greater volume than the deteriorated metal. In advanced cases, entire sections of the concrete are spalled off thereby exposing the reinforcement to the atmosphere. Corrosion cracks usually progress most rapidly where shearing stresses are the greatest and where slipping occurs due to loss of bond.

As the corrosion reaction progresses with continued destruction of the reinforcement at the anodic regions, a migration of alkali ions to the cathodic areas takes place. If the corrosion cell potential is sufficiently high, alkaline compounds will precipitate out on the reinforcement and cause a subsequent loss in bond strength. However, such a reaction is usually predominant only when external voltages are applied to the system and, therefore, is not characteristic of natural corrosion.

Protective properties of concrete

Under most conditions, portland cement concrete provides the reinforcement with good protection from corrosion. The protective value of concrete is derived from its high alkalinity and from its low electrical conductivity in atmospheric exposure. Shalon and Raphael found the average pH of mortar mixed with tap water to be about 12.8. By further investigation they concluded that complete inhibition of corrosion apparently occurs when the pH is equal to or greater than 12.

This passivation process associated with high alkalinity is best explained by a brief

description of the mechanism of protection given by Unz, and Mayne and Mentor.[17] The galvanic conditions produce anodic and cathodic regions. In the anodic zones ferrous ions go into solution and are oxidized forming a soluble ferrous hydroxide. In the presence of oxygen and alkali, however, the solubility of ferrous hydroxide is diminished, and instead of passing into solution it is converted to a hydrated ferric oxide (γ—Fe_2O_3 H_2O) in physical contact with the reinforcement. It is suggested, then, that this oxide arises from the oxidation of ferrous hydroxide produced by an anodic discharge of hydroxyl ions on the metal surface. As this process continues, the half-cell (open circuit) potential becomes more noble and with subsequent reaction this "cement skin" of insoluble ferric oxide becomes stronger. The electrical resistance of this coating rises up to an asymptotic maximum value and a state of equilibrium is eventually reached. If, however, there are serious breaks in the coating, such as large voids adjacent to the reinforcement, the equilibrium state breaks down and corrosion ensues.

Dry concrete is almost a perfect electrical insulator, however, the smallest amount of humidity gives it considerable conductivity. As the concrete dries with aging the resistivity increases thereby inhibiting macrocell reactions.

PREVENTION OF CORROSION

Structural design—Adequate amount of cover

In the design of structures care should be taken to avoid dangerous features which may lead to corrosive condition ; such as poor drainage systems which allow collected water to flow over the concrete instead of being thrown clear. Pools of rainwater on roof slabs or bridge decks can leach out the hydroxides from the concrete and collections of saline water can make salt available for penetrations. In structures located in a corrosive environment, reinforcement should be held to a minimum in members not subject to high loading such as hand rails, balustrading, curbs, walkways, and the like.

Probably, one of the more important factors associated with structural design is the amount of cover. This factor must obviously be considered with permeability (*i.e.*, the quality of the concrete mix) since 2 in. of permeable concrete may afford less protection to the reinforcement than 1/4 in. of impermeable concrete. The required thickness of cover also depends on the environment and exposure of the structure. Because of this, various requirements have been suggested depending on the environmental conditions and the quality of concrete used.

In marine environments, Lewis and Copenhagen suggest a minimum cover of 3 in. and state that 2 in. is essential. The Port of Los Angeles sets a minimum of 3 in. for marine exposure. AREA specifies a 3-in. cover from plane and curved surfaces and a 4-in. cover at corners. AASHO specifies a 4-in. cover.

The exposure of concrete on inland structures generally does not present a corrosion problem. However, in locations where de-icing materials are often used, AASHO recommends 2 in. of cover in roadway decks and adjacent appurtenances such as curbs, sidewalks and railings.

Some investigators who have studied the problem of adequate cover concluded that increasing the depth of cover is not as effective as one might suspect. Pletta, Massie, and Robins, for example, state that the rate of

corrosion decreases with an increase in cover up to about 1/2 in.; thereafter, little change is noticeable. Kinnemann,[18] observed that 1/2 in. of high quality concrete will completely protect the reinforcement from salt water corrosion. Therefore, adequate depth of cover cannot be recommended unless specifications are set on the quality of the concrete.

High quality concrete mixture

For a given thickness of cover, the permeability of the concrete will determine the degree of penetration for a given environment. Using modern concrete technology, it is possible to design a high quality, impermeable concrete which will greatly sustain the life of a structure in a corrosive environment. Concrete permeability has been found to rely on numerous factors, the more important ones being : water-cement ratio, cement-aggregate ratio, aggregate grading, and consistency. Shalon and Raphael give the following definition for a high quality concrete : "The kind of concrete which can be achieved only by close attention to every detail in connection with the selection of materials, proportioning of the mix to produce a truly plastic concrete having a relatively low water-cement ratio, and thorough consolidation of the concrete as placed."

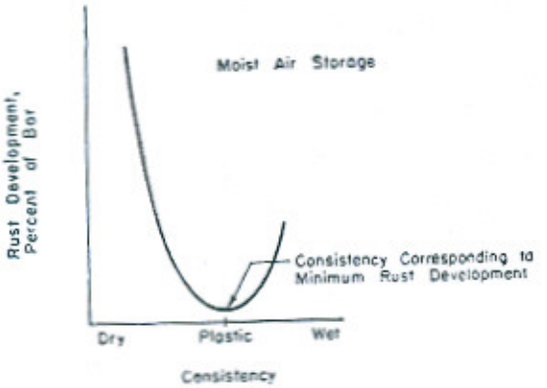


Fig. 8—Relation between consistency of concrete and rusting of reinforcement after 2 years.

Tyler found that, in general, a concrete mix having a low water-cement ratio afforded better protection than a mix of similar consistency having a high water-cement ratio. Low water-cement ratios require higher cement factors than normally needed for strength requirements. For marine construction, the Port of Los Angeles recommends a cement factor of 7 sacks per cu yd. AASHO and AREA suggest a minimum cement factor of 6.

A specification on the water-cement ratio, however, is not valid unless the mix consistency is also considered. The consistency of concerete has a pronounced effect on the corrosion rate which is not governed only by thew ater-cement ratio or the cement content. In general, the rate of corrosion is greater for very dry and very wet mixes than it is for mixes of plastic consistency. There appears to be an optimum consistency at which the amount of corrosion is almost completely diminished. This is illustrated by the qualitative curve shown in Fig. 8 drawn up from data obtained from specimens exposed to moist air for 2 years. The results of these tests indicate that consistency has a marked influence on the protective value of concrete and that water-cement ratio does not in itself control the corrosion rate of the reinforcement.

Varying the cement-aggregate ratio likewise has an effect on the corrosion rate as indicated in Fig. 9. The results of this series are questionable because one cannot be sure if moist air storage is a reliable index for outdoor exposure. In any event the results do show that a lean mix affords little protection as indicated by the time-rust curve for a 1 : 10 cement-aggregate ratio.

Aggregate gradation is another factor which should be considered for high quality concrete. Well-graded aggregate is an important requisite for low permeable concrete. Data taken by Friedland indicated

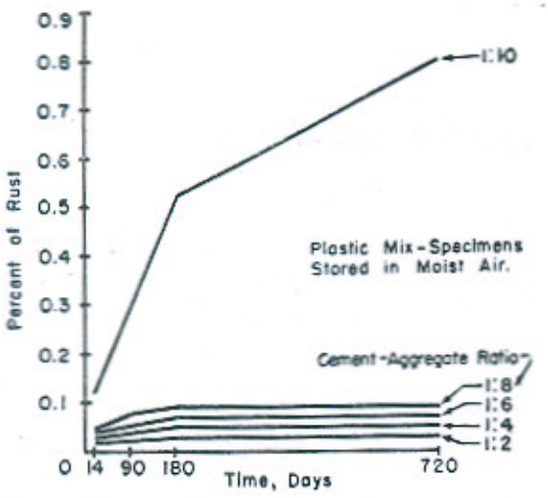


Fig. 9—Time-rust relationship in concrete showing effect on varying the cement-aggregate ratio

that coarser grading enhances the protective quality of concrete ; however, the spread of data was too great to warrant definite conclusions.

Due to the influence of these various factors it is possible to increase the protective qualities of concrete by proper proportioning of the materials. A high quality, impermeable concrete is perhaps the most effective means of corrosion prevention. However, it should be pointed out that no matter how precisely the mix specifications are prepared, careful supervision and site control is required to insure that proper mixing and placing techniques are followed.

Nonreactive materials

To maintain the protective properties of a well proportioned concrete, care should be taken to avoid the use of materials which are reactive or otherwise undesirable from the corrosion point of view. Water and additives containing salts, particularly chlorides, should not be used. The use of aggregates which contain high salt contents should be avoided. As an additional precaution, any salt deposits that may have formed on the reinforcement should be washed off before it is placed.

Some lightweight aggregates and other types of aggregates exhibit high permeabilities and shrinkage characteristics and should not be used for structures in a corrosive environment. Preliminary tests have shown that the protection afforded to reinforcement may be less for concrete made with lightweight aggregate than for a comparable concrete made with natural aggregates.

Since portland blast furnace slag cement lowers the passivity of the reinforcement it has been suggested that such a cement may promote an intensified corrosive attack, however this has not been shown to be the case. Tests reported by Mather indicated that rusting of reinforcing steel was significantly less in concrete made with two portland blast furnace slag cements than in a concrete made of Type II portland cement. However, little corrosion was noted for any of the cements tested even for unreported tests where the specimens were exposed to sea water.

Cathodic protection

The general principle involved in cathodic protection is to make the reinforcement cathodic to some exterior anode. Two methods of cathodic protection have been introduced. In one method the anode is a sacrificial metal, such as zinc, in which case the flow of current is induced by galvanic

means. This system requires that the anodes be replaced as they are deteriorated. The second and most common method is one in which a current is impressed between the reinforcement and an exterior anode (usually carbon) which need not be sacrificial in nature.

Although this method has proven effective, there are many problems involved in applying its use to reinforced concrete structures. One of the problems, for example, is that the entire system of reinforcement must be electrically continuous for effective protection. A lack of complete electrical connection of one or more bars would set up isolated corrosion systems causing intensified attack under the action of impressed current. Also, the cathodic metallic circuit should have a low, uniform sensitivity so that large potentials are not required to provide adequate currents. It is doubtful, then, if cathodic protection could be used more economically than a program of routine repair of the structure as corrosion defects appear.

Surface coatings

The purpose of impervious surface coatings is to prevent the absorption of exterior salts and other aggressive substances into the concrete. They are also used to equalize moisture contents by reducing evaporation or absorption of moisture which occurs with each weather change. There are many types of surface coatings being investigated ; some of the more common ones being : paints, coal tars, cutback asphalts, and asphalt emulsions.

Bituminous coatings are usually not effective unless they are preceded by applications of some kind of primer coat. Penetrating primers such as coal tar or asphalt base impregnate the pores and hairline cracks. A bituminous solution or a hot bituminous membrane is then applied over the primer followed by a coat of white wash for thermal protection. Cutback asphalts are also used for primers, however, they require suitable solvents for proper penetration.

Asphalt emulsions have been used for wet concrete surfaces, after curing or in rainy weather, but such emulsions appear to have smaller insulating resistances.

Resistivity tests on coated specimens have been conducted to obtain a practical evaluation of the insulating properties of the various bituminous coatings. The following resistance ratios were obtained with respect to uncoated specimens made of the same mortar batch :—

Coal tar paint with filler	..	5-10
Cutback asphalt	..	3-5
Asphalt emulsion with filler	..	1-2
Uncoated mortar specimens	..	1

Although impervious surface coatings have displayed a certain degree of effectiveness, they have a tendency to maintain high moisture contents within the concrete and thereby reduce the electrical resistivity. These coatings also seem to somehow increase the ratio of cathodic areas to anodic areas and as a result, localize and intensify corrosion. Therefore, the effectiveness of surface coatings is certainly questionable and in many cases may do more harm than good.

Oxygen starvation

Depolarization of corrosion cells set up by various environmental conditions may be prevented by reducing the access of oxygen to the reinforcement in cathodic areas. If a concrete specimen containing two steel electrodes is immersed in water, thereby

reducing the accessibility of oxygen to the steel, the electrochemical currents due to differential salt contents will be greatly lowered.

Anodic inhibitors

Anodic inhibitors contain materials such as alkalies, phosphates and chromates which form either iron salts or a ferric oxide film on the anodic surface thus preventing ferrous ions from entering the solution. Such anodic inhibitors are effective only in high concentrations. If they are added in insufficient quantities, the corrosion reaction may be locally intensified. On the other hand, high concentrations may adversely affect the concrete. Therefore, the use of conventional anodic inhibitors cannot be recommended until more complete and fundamental investigations have been conducted.

Construction techniques

There are many operations in construction that could perpetuate serious difficulties if carried out improperly or contrary to known good practices. First class workmanship is of major importance for structures in environments which may cause corrosion problems.

The concrete, when placed, should be thoroughly vibrated and compacted to insure against excessive voids in the concrete. Large voids adjacent to the reinforcement may contain high moisture contents, thus allowing the possibility of macrocell corrosion to take place.

The concrete should be placed such that the thickness of cover is uniform throughout. Evenness of cover over the reinforcement plays an important role in protection against corrosion. In many cases it has proven to be more decisive than the quality of the concrete.

The reinforcement should not come in contact with soil, bricks, wood and other porous nonalkaline material.

A helpful operation suggested by Unz is to place a priming coat of pure portland cement slurry over the reinforcement immediately followed by the concrete. This method, if carried out properly, will create a continuous, cement skin which may do much to protect the reinforcement from corrosion.

There are numerous other techniques that should be followed which will not be listed here. Most of these have varying degrees of importance depending on the type of structure and the environmental conditions. It is highly important that the specification of these operations be followed up by careful one-site supervision and inspection.

West Pakistan Engineering Congress 1966

The forty-ninth session of the Congress was held from 17th Oct. to 26th October. Dr. M. A. Hamid former Chief Engineering Advisor, Government of West Pakistan, inaugurated the Conference. The presidential address was delivered by Mr. A. M. Akhund, followed by an address by Dr. Hamid. This issue contains a brief report of the activities of the Congress.

Mr. Akhund addressed Dr. M. A. Hamid, distinguished guests and members of the Engineering Congress as follows :

It is a matter of great pleasure for all of us to have you, Dr. Hamid, amongst us this morning at the 49th Annual Session of the West Pakistan Engineering Congress. On behalf of the members of the Congress, I have the privilege to welcome you most heartily and to thank you for accepting our invitation to be the Chief Guest on this memorable day. We feel elated and are proud to have the privilege of one of the most eminent and distinguished Engineers of the country, inaugurating this Annual Engineering Session. This will inspire the members of the Engineering Congress and encourage them to redouble their efforts in the service of the country and the Engineering profession.

The Engineering Congress is the oldest representative body of Engineering profession in the country. Its membership reflects all aspects of engineering activity in the Province both in Public and Private sectors. Its membership today stands at 1,075.

Since the last annual session, Pakistan has been through struggles of life and death. In April, 1965, an attempt was made by the Indian Forces to enter the Pakistan soil in the Rann of Katch area. This was repulsed and a convincing defeat was inflicted on the enemy. On the 6th September, 1965, a full-scale, undeclared war was waged by India treacherously. In this hour of trial, it was the proud privilege of the great many members of this Congress to work for and with the Armed Forces in the defence of our homeland. The Engineers, in responding to the national call, discharged their duties with an exemplary sense of dedication and devotion. The trains were kept running night and day in forward and other areas in spite of shells and air attacks and in spite of

total blackout conditions at night. The communication lines stood fast and the canals were kept flowing. The B.R.B.D. Canal has gone down as a glorious landmark in the history of Irrigation Works. It responded excellently and was kept flowing in spite of enemy attacks. The vital industries and essential services were maintained. The Civil Defence Organizations, in Public and Private sectors, under the able guidance of the Engineers, worked as a team and maintained the morale of the masses. After the cessation of the war, the work of rehabilitation of displaced persons in the war affected areas was, undertaken with utmost speed and efficiency by all branches of the Engineering profession. In all this process, the Engineers enabled our valiant Defence Services to beat theene my assault and give them a crushing defeat. Today, under the dynamic leadership of Field-Marshal Muhammad Ayub Khan, President of Pakistan, the country has been able to establish for itself a place of honour and dignity in the nations of the world. The performance of the Members of the Engineering profession in this national hour of trial was recognized by the Government and some of the Members of the Congress were conferred with various awards. I wish to congratulate them, on behalf of the Congress, for the honour bestowed on them by the Government.

While commending our efforts and activities during the national emergency, we have to think of the heavier and more onerous tasks which lie ahead of us. For the enormous developmental activity required to be undertaken during the Third Five Year Plan, which is very arduous indeed, we must address ourselves in a spirit of dedication and with a will to succeed in fulfilling the targets in the national interests. The old motto of the Engineering Congress 'PROSPERITY AND PROGRESS' must be kept aloft by rededicating ourselves to the service of the country. I have no doubt whatsoever, that we will succeed in meeting the tremendous challenge to our ability to deliver the goods. The same standard of service will be needed from us during the current Plan Period and for the enormous task ahead of us, we should keep up the tempo generated by the recent war and don't let it sag or flag. The war is over but its tempo must continue unabated.

Phenomenal progress was made by the country during the Second Plan Period in all Branches of Engineering both in Public and Private sectors. It was a very healthy sign and indicated the determination of Pakistani Engineers to prepare and train themselves to the task of handling problems of even greater dimensions which we have now been called upon to face in the planning and execution of the gigantic Third Five Year Plan launched by the Government. In the national interests, we have to rededicate ourselves to the task of making the Third Five Year Plan equally successful.

The colossal development programme, envisaged in the Third Five Year Plan, throws out a challenge to us, as about 75% of the Plan provision will be spent on projects to be executed directly or indirectly by the Engineers. This by itself brings out to forefront the importance of the part the Engineers have to play in the country's future progress. The progress and prosperity of the country has by and large to depend on the efforts and achievements of the Engineers.

Agriculture is the most vital industry of Pakistan as it is the mainstay of our economy and stability. The Government has given the highest priority to the development of agriculture for achieving self-sufficiency in

food and thereby to save the colossal drain on our foreign exchange. In this task, the Engineers of this Congress, in particular those of the Irrigation Department, WAPDA, A.D.C., Land & Water Development Board and the Small Dams Organization, have to play a vital role. The Engineers of the Congress are fully alive to this national development programme and wish to assure the Government that they would do their utmost to enable them to achieve the objectives set. For optimum agricultural production, it is, however, very necessary to introduce improved agricultural parctices including the most economic use of irrigation water supplies which are still very limited. For this purpose and for the development of salinity resistant crops, the Agriculture & Irrigation Departments need further and closer collaboration, particularly in the fields of research.

The sources of foreign exchange for Pakistan are very limited. Foreign Aids and Loans have been obtained by the Government with considerable difficulty to finance the various development projects. Recently, the Government have launched a special drive to earn more foreign exchange by boosting up the export of selected agricultural and industrial products and also to curtail the foreign expenditure to the barest minimum. In this task, the Engineers of this Congress can play a very vital and positive role and I am confident that in the national interest, they will leave no stone unturned to help the Government to achieve speedily the objective of self-sufficiency and to avoid dependence on foreign aids and loans. The production capacity of the various industrial units both in public and private sectors should be increased by improving the production methods, balancing the shop productions and machinery and standardizing the shop products to avoid wastage. Surplus manual labour is still available in abundance in the country and I would suggest for the consideration of my fellow Engineers that the maximum use of this available manpower should be made in the planning and execution of our various development projects, specially in the construction of dams, embankments, bunds, etc. Modern machinery, equipment and other appliances may be used prudently wherever most essential as aids to manpower to maintain the required output, to speed up the work and not merely for the elimination of manpower. This will go a long way in curtailing the foreign exchange expenditure on the procurement of the machinery, their spare parts and the various oils and oil products required for the operation and maintenance of the machines.

The Engineers can also greatly help the Government in their objective, if we make greater use of the indigenous raw materials as well as locally manufactured products, plant and equipment on the various engineering projects. Construction of prestige structures and buildings except perhaps those of great national importance, should be avoided to reduce the construction costs and enormous foreign exchange.

As I have stated earlier, the responsibility for the rapid and economical development of the country lies fairly and squarely on the shoulders of the Engineers. The Members of the Congress while accepting this responsibility, however, wish to draw the attention of the Government that without a Steel Mill, it will not be possible to set up the basic heavy industries in the country and the programme of rapid and economical development in the industrial sector cannot be achieved. The heavy drain on foreign

exchange will continue and may well increase further with serious repercussions on our national economy. The oft-repeated objective of raising the standard of living of the common man will continue to elude us unless the basic and heavy industries are established. While appreciating the efforts of the Government in this direction we sanguinely hope that this long cherished desire of having a Steel Mill and integrated steel works of our own will be fulfilled in the near future.

In the initial stages of developmental activity in Pakistan, undertaken on an unprecedented scale through the Agency of WAPDA, it was necessary to secure the services of specialists and expert Consultants of international repute from abroad. It was likewise also proper to invite major foreign contractors to undertake gigantic engineering works which could be undertaken only with modern equipment and machinery. In the past few years, many Pakistani Engineers of outstanding ability and technical acumen have had the privilege of working closely and in direct association with the Foreign Consultants and Contractors and have ably acquired the latest and up to date technical know-how and expert knowledge and are now quite competent to undertake similar jobs independently. To curtail foreign exchange expenditure, the Engineering Congress would advise the Government to reduce dependence on foreign consultants and foreign contractors and to employ more and more Pakistani Consultants and Pakistani Contractors in the planning and execution of their further development projects. Foreign experts and specialists may be employed as Associate Consultants by the Pakistani Consultants in any specialized fields, where considered necessary. Similarly, the Pakistani Contractors may associate any Foreign Specialist Firms in the execution of the development projects. Such a step will also ensure that Pakistani Engineers will plan, design and execute the projects making maximum use of the suitable indigenous materials and manpower and other local and readily available appliances. As you are aware, the Government have again refixed the retiring age of Government servants at 55 years and it would now be possible for a large number of experienced and capable Engineers, being available for developing Consulting Services in the various fields of Engineering and also organizing major Construction Concerns and Organizations. May we, therefore, urge the Government and the Private Sector to revise their existing policy and seriously consider appointing Pakistani Consultants and Pakistani Engineers in the planning and execution for their development projects, in the national interest.

In pursuance of the recommendations made from the platform of the Congress in the recent past, a full-fledged University of Engineering & Technology set up at Lahore has been doing excellent work over the last few years. It is gratifying to observe that apart from the Under-Graduate courses in Civil, Mechanical, Electrical, Mining, Architecture, Town Planning, Chemical and Metallurgical Engineering, the University has started Post-Graduate courses leading to Master's Degree in Public Health, Town Planning, Soil Mechanics, Foundation Engineering, Structural, Hydraulic and Irrigation, Electrical and Production Engineering. Following the Indo-Pakistan War in September, 1965, the Government have stopped further activity on the University Construction programme at Lahore and have decided to shift the University outside

Lahore. The new site for the University has not yet been finally selected. We hope that a wise decision will be taken on the new site shortly.

The Engineering Colleges in the Province and the various Polytechnic Schools set up in the various towns are also doing good work and producing more and more Engineering Graduates and Sub-Engineers to meet the growing demand in the country. The profession is, however, lacking facilities to impart training to practising Engineers at appropriate levels to keep themselves abreast with the latest and new techniques in the field of Engineering. This matter has been agitating the minds of the Engineers for some considerable time and the Engineering profession has been repeatedly demanding this greatly needed training facility since many years. We again urge the Government in the larger interest of the Engineering profession and the country that as in the case of other Services, an Engineering Academy should be set up in West Pakistan without further delay.

The Engineers, as responsible citizens of Pakistan, have always strived hard and worked shoulder to shoulder with the Government for the progress and prosperity of the country and would continue unconditionally in implementing these policies and programmes faithfully. While they have unflinching faith and confidence in their benign Government of the day, they would like to address to them that it would be in the greater interest of the Government and the country to associate the distinguished talent from the Engineering profession in their Councils and give them greater voice in shaping the larger polices of the Government and taking important decisions in nation-building activities. The Engineering fraternity, therefore, appeals to the Government to restore the right position of the Engineers in the professional fields. Likewise, they earnestly appeal to the Government to consider the case of early absorption of temporary engineers in the various departments of the Government in the overall interest of the engineering profession.

The Engineering Congress has, I have to express with regret, not been able to fulfil the objects of promoting the science, practice and profession of engineering to the extent as every one of us would have wished for. This is primarily due to the Congress having no house of its own where it could live and function. For all these years the Congress has worked under this serious handicap. I had, therefore, applied myself wholeheartedly to find a suitable piece of land to build a befitting Engineering House for the Congress as without such a Centre, the activities of the Congress can hardly be galvanized. This long-cherished desire is ultimately going to be fulfilled soon. We are most grateful to the Lahore Improvement Trust and its Chairman, who have allotted us a plot of land in Gulberg area. A Building Sub-Committee with Dr. Mubashir Hasan as the Convener has been entrusted with the functions of planning and collection of funds for the construction of the permanent headquarters building on behalf of the Congress. The matter has been left in the hands of efficient and capable colleagues, who are striving hard to make the Congress House a reality in the shortest possible time. I would request my brother Engineers to come forward and donate liberally for raising a modern and befitting structure for the Engineering Congress House.

In accordance with the wishes of the Engineering Congress expressed at the last

Annual Convention, a Commission was constituted who have evolved a 'Code of Ethics' for upholding the prestige of the Engineering Profession in Pakistan which will come up for consideration and approval of the General Body at this Session. The Congress at their last Session had also charged the Commission with the responsibility of amending the Memorandum of Association governing the Engineering Congress so as to revitalize the Congress. The Commission have prepared certain amendments which will also be placed before the Congress for consideration and approval at this Session.

I would now like to briefly review the activities of some of the major Engineering Departments/Agencies working in the Province.

P. W. Railway

The construction of a 50-mile long broad gauge rail link from Kot Adu to Dera Ghazi Khan passing over Taunsa Barrage is well underway and the line is expected to be completed and opened to traffic in 1968. It has also been decided by the Government to extend this line by another 142 miles to connect Dera Ghazi Khan to Kashmor. When completed by the end of the Third Plan Period, this line will provide an alternative rail link to Quetta and Karachi along the right bank of the River Indus and will greatly help in speeding up the development of the region.

The work on the conversion of 40-mile long metre gauge section between Hyderabad and Mirpur Khas to broad gauge is also well in progress and is expected to be completed by the middle of 1967.

In addition, work is in progress on Phase II of the Karachi Circular Railway to connect Wazir Mansion Station with Karachi City Station and this is expected to be completed during the Third Plan Period.

Work has been taken in hand on the replacement of the old railway bridge over Sukkur Channel of the River Indus comprising ing 1 ×230′, 1 ×300′ and 1 ×100′ triangulated girder spans and is scheduled for completion by 1968.

Detailed Traffic and Engineering Surveys have been carried out for a broad gauge railway line and loop spur to serve Federal Capital area at Islamabad and for extending the railway line from Chaman to Spin Baldak, in Afghanistan.

Preliminary works have been taken in hand for setting up a modern Railway Carriage Factory near Rawalpindi. When completed by the end of the Third Plan Period, the Factory will be capable of manufacturing 150 all-welded steel carriages every year.

A modern factory to manufacture pre-stressed concrete sleepers is being installed at Sukkur which is scheduled to go into production early in 1976 with an initial production capacity of 80,000 sleepers per annum raising to 2,00,000 sleepers a year in a phased programme of two years.

The project relating to the electrification of the Khanewal-Lahore Section, a length of 178 miles, has been sanctioned by the Government. The work has been let out to a British Consortium of Contractors and arrangements are being made to proceed with the work. The project is expected to be completed and brought into operation by the end of the Third Plan Period.

Over 400 miles of main line tracks between Karachi and Lalamusa have been modernized by renewal with heavier rails, increased sleeper density and ballast cushion with half mile long welded rails by 'Quick Thermit'

process. Steps have also been taken towards the partial mechanization of track renewals and track maintenance.

The main line between Temple Dera and Jhatpat stations on Sukkur-Sibi Section has been raised and made flood-proof. Dips on other important sections, as approved by Flood Commission, are being replaced with bridges to obviate inerruption to traffic.

The signalling system on the main lines of the Railway is being modernized by the provision of all-relay interlocking, tokenless block working, track circuiting and providing automatic block signalling on certain stations/sections.

Three road overbridges at Hyderabad, Multan and Wazirabad are already under construction. One more at Taraki on the G.T. Road will be taken in hand shortly.

Communication and Works Department

The activities and achievements of the B & R Department in the Province of West Pakistan in the field of new constructions, improvements and maintenance of roads, bridges and buildings during the year 1964-65 were particularly heavy. 1378 miles of new metalled roads were constructed besides the improvements to 307 miles of existing roads. Work remained in progress during the year on 735 miles of roads.

The construction work of the new road bridge over the River Jhelum, 3,300 ft. in length, with prestressed concrete superstructure, is well in progress and is expected to be completed by the end of 1967.

The work on the construction of 3 other major road bridges, two over the River Ravi, one at Shahdara and the other at Chichawatni and one over the River Sutlej near Adamwahan, has also been taken in hand and is proceeding with utmost speed.

Besides, a number of other bridges, including the Deg Nullah Bridge on Narowal-Pasrur Road, Niawela Bridge on Indus Highway and Sohan Bridge on Cherah Karore Road are under construction. The road bridge over Malir River near Karachi has been completed and opened to traffic.

A very large number of important buildings, like schools, hospitals, colleges and dispensaries, etc. for various Government Departments were constructed by the Department during the period under review throughout the Province.

The Highways Organization has completed feasibility studies and detailed designing of some of the following projects:—

1. Karachi-Hyderabad Super-Highway.
2. Hyderabad - Reti Multan - Lahore Highway.
3. Lahore-Sargodha-Khushab Highway.
4. Lahore-Lyallpur Highway.
5. D. I. Khan Bridge over River Indus.

The Road Research Laboratory and the Building Research Directorate have done commendable experimental work in the various fields of activities useful to the Engineering profession.

During the year under review, development and construction work was continued for the Lahore Township, Shadman Colony, Rivaz Gardens and Widening the Mall Schemes and for the preparation of Housing Schemes for various District Headquarters in the Province.

Irrigation Department

West Pakistan possesses one of the finest and largest irrigation systems in the world today and the Irrigation Department has continued to play its very important role in maintaining efficiently this magnificent system.

The canals are the lifeblood of West Pakistan and the mainstay of its agricultural prosperity and industrial progress. The Irrigation Department have undertaken successfully the construction of a number of irrigation systems, high level canals, lift irrigation schemes, pumping schemes and drainage schemes throughout the Province. The Department is responsible for Flood Control and Land Reclamation. The irrigation Research Institute is doing most valuable and commendable research and experimental work and is the best Institute of its kind in the whole of Asia. With the additional facilities now being added to this Institute, it is expected to play still greater role in guiding and advising the Engineering Profession on the increasing problems connected with Hydrology and Water Engineering. The work on the construction of Thatta-Sujawal Road Bridge over the River Indus by the Irrigation Department is progressing satisfactorily which when completed, will play a great role in the social and economic uplift of the people of the region.

WAPDA

Under the Water Development Projects, Hub Dam Project on Hub River near Karachi, Khanpur Dam on Haro River in Hazara District, Gomal Dam on Gomal River in D. I. Khan and Tanda Dam in Kohat District and a number of reclamation schemes are now in various stages of construction according to the scheduled programme.

The work on the construction of the famous WAPDA House on the Mall is progressing satisfactorily and is expected to be completed very shortly.

The Indus Basin Project consists of 2 dams, 8 inter river link canals, 5 barrages, 1 gated syphon, remodelling of 3 existing inter river link canals, 2 existing headworks and some existing irrigation canal systems effected by new constructions. The works have been divided in three phases. First phase works comprising the Trimmu-Sidhnai-Mailsi-Bahawal Link System have since been completed and are functioning. These have since been transferred to the Irrigation Department for maintenance and operation.

Second Phase Works comprising Mangla Dam, Rasul-Qadirabad-Balloki-Sulaimanki Link System and Marala Barrage are in various stages of construction. Arrangements are being made by WAPDA to let out the remaining contracts for Third Phase Works comprising Chashma Barrage, Chashma-Jhelum Link, Taunsa-Panjnad Link and Tarbela Dam within the current year.

All major Remodelling works have also been completed except a few works, which would now be undertaken by the Irrigation Department.

Satisfactory progress was achieved in the field of salinity control and reclamation by the Ground Water and Reclamation Division of WAPDA during the period under review on the installation of tube-wells and construction of drains etc. under various projects throughout the Province.

The Power Wing of WAPDA maintained its pace of developing the power potential of the Province. On generation side, two transportable gas turbines, aggregating 24,000 K.W. have been installed at Lahore and have been brought into commission. A Thermal station of 25,000 K.W. capacity at Sukkur was completed and the Hyderabad Thermal station was extended by 8,000 K.W. In the Northern Grid area, the Secondary Transmission and Distribution scheme was completed during the year. In addition to that, second circuit of 220 K.V. line from

Multan to Lyallpur was strung on the existing double circuit towers. This will enable the transmission of additional power of 1,30,000 K. W. available from Multan Power Station.

There has been an appreciable expansion of distribution network both in the Northern and Southern regions of the Province giving an addition of 3,700 circuit miles. Electricity supply was made available to 171 new towns and villages and 98,000 connections were given to the consumers of all categories.

Land & Water Development Board

The progress achieved by the Land & Water Development Board through the integrated application of all the factors of agricultural production has been marvellous. Almost 2,47,000 acres of affected land has already been restored to full production. The operation of about 2,000 tube wells installed in the area had made available during the year about 25 lakhs acre feet of additional water. This has made up the deficiency of irrigation supplies, provided the additional supplies of water for washing down the salts and has lowered the water table by about 8 ft. up to end of September, 1965. The cropped area has increased by 3,65,000 acres, the average yield per acre has gone up by about 30%. The successful operation of the project has neutralized the greatest enemy of growth of agricultural production, *viz.* the waterlogging and salinity.

Public Health Engineering Department

A scheme for water supply and drainage for Lahore City has been prepared by Consultants at a total cost of Rs. 45 crores for which necessary loan is being negotiated from the World Bank.

Schemes for 28 cities in West Pakistan, including commodity aid for Sheikhupura, Gujranwala, Multan, Nawabshah and Hyderabad are now under preparation by the Consultants.

In the recent war with India, this Department rendered invaluable assistance towards the upkeep of civic life of important towns of the Province. Civil Defence Emergency Schemes for 30 classified towns were prepared by them. They also greatly helped in the rehabilitation of war affected population in Sialkot and Lahore Sectors by cleaning wells and providing substitute water supply and drainage arrangements.

Agricultural Development Corporation

Agricultural Development Corporation is constructing dams, some of which are high dams, to store flood supplies whcih would have otherwise gone waste causing damages on their way to the sea. These stored supplies are used for local irrigation increasing the country's food production and fish culture. The storages also help in preventing erosion and securing soil conservation. The aim of the A.D.C. is to build about 500 such dams in West Pakistan. A start has already been made in this direction. Nine dams have been completed, six are under various stages of construction and ten are under various stages of investigation, design and sanction. These projects are being undertaken entirely by Pakistani Engineers.

Before I conclude, I wish to express my profound thanks to you, Sir, once again for honouring us with your presence today. I am also thankful to the distinguished guests who have made it convenient to join our function. I take this opportunity to thank my colleagues, the Members of the Council and the office-bearers for their fullest co-operation and assistance during deliberations of the Council meetings. My thanks are particularly due to Mr. C. A. Vali, Honorary

Secretary of the Congress and Mirza Abdul Latif, Secretary of the Engineering Commission, for their most valuable and selfless work done by them throughout the year and during this Session. I also thank the Press for giving the Engineering Congress due publicity and coverage for enhancing the cause of Engineering Profession in the country.

I now request you, Sir, to kindly inaugurate the 49th Session of the West Pakistan Engineering Congress.

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INDEX TO ADVERTISERS

Mr. M. A. Hamid Guest of Honour addressed the Engineers

The former Engineering Adviser to the Pakistan Government, Mr. M. A. Hamid, while inaugurating the 49th Annual Engineering Congress in Lahore, observed that the planning for the control of floods, salinity and waterlogging was at best sketchy and far more detailed and vigorous effort was called for to fight the menace. Extracts from his address are as under.

"Great responsibilities devolved on the engineers for implementing the development plans. It was a big task, in fact, a stupendous task which was a challenge to the capabilities and courage of the engineers of the country. When Pakistan was born, most of the technical personnels were lost to the country, and those who were convinced that Pakistan could never be a viable State, had looked forward to the day when it would collapse because of the meagre services to carry the burden. The engineers had shown to the world that they could rise to the occasion and accept the challenge. But the challenge was still there, and the consequences of failure on the part of the engineers could now be more serious than they were ever before."

Addressing the young engineers, Mr. Hamid emphasised the urgency of tackling the flood problem and the importance of conducting research to understand problems like floods, salinity and waterlogging. "These problems were not peculiar to Pakistan and no country or people in the world could claim exclusive knowledge in these fields."

Houses for Common Man

"Pakistan could not afford to construct prestige buildings as there was neither the time nor the resources to indulge in this luxury. What the people needed were decent houses for the common man who had one of the lowest levels of income in the world. We need a complete reorientation of our ideas and devotion to obtain for our people the maximum benefit for every paisa that we spend."

"But on the other hand, when large public structures of importance are built, they should remind us of the Islamic traditions of the past."

As regard developing technical education and providing technical training, "We need

many schools of engineering to teach the surveyors, the draftsmen and the overseers of which there is an acute shortage."

"In the Engineering University, there was always a tussle between two view-points—one seeking to increase the output and the other the quality. Personally I was in favour of increasing the emphasis on quality, so that the engineers who received bachelor's degrees were really first class. Facilities for higher education, particularly for research, had to be developed as fast as possible since the entire burden could not be shouldered by the Government. I appeal to the industrial magnates to emulate the example of their counterparts elsewhere as it were they who would reap the harvest of industrial research."

The Government might also consider granting them an exemption from tax on the amount of money that they spent on research.

"I again re-emphasise the great need for setting up an academy for engineers. Its establishment is overdue. I have to put a word about the number of engineers seeking jobs outside Pakistan. It is a terrible wastage of national efforts."

Service Conditions

The Government had improved the pay scales and conditions of service of the engineers, but we are not living in static conditions. The index of cost of living is rising which has offset the small improvements made in salaries. Although Pakistan is a welfare State, there are a number of social services still to be provided for. For instance, there is no national health service, no guarantee for children's education up to a certain age beyond which it is heavily subsidised. All these services make a deep cut in the monthly budget. The Congress has evolved a code of ethics. I advise the engineers to follow this code framed for them. I strongly feel it is time to arrest the present tendency to dub every one but dishonest and corrupt. In fact, it is considered very fashionable to discuss nothing but wild stories of corruption. May I say that it is most demoralising for the honest worker. You must take prompt and effective measures against those who are genuinely at fault but we are not serving the best interests of the country by painting every one black without positive proof."

"Lastly I would strongly endorse the feelings that the engineers had not been given due recognition of the role they were called upon to play. It is advisable for the Central and the Provincial Governments to implement the recommendations made by the Pay and Services Commission and the Services Structure Committee several years ago.

Technical Activities of the Congress

This year nine papers on the subject of Irrigation, Building Construction, Railways and Electric Power were presented and discussed. Brief excerpts and synopses of these would be given in the forthcoming issue.

Forthcoming International Conferences

SYMPOSIUM ON FLOODS AND THEIR COMPUTATION

International Hydrological Decade

A symposium on floods and their computation is to be held in Leningrad, U.S.S.R. from 15th to 22nd August 1967. The symposium is organized jointly by UNESCO, World Meteorological Organization and Government of U.S.S.R. International Association of Scientific Hydrology is also cooperating in the symposium. The subjects of discussion include the follcwing :—

(I) Theory of the Formation of Rainfall Floods:

Methods of determining possible reduction in space and time of run off caused by excessive rainfall :

Determination of areas of simultaneous run off, time lag ;

Determination of water losses and temporary storage ;

Computation of maximum discharge of rainfall-floods in cases—

(*a*) of absence or insufficiency of hydrological data ;

(*b*) of availability of hydrological data.

(II) Theory of the Formation of Snow Melt Floods

Determination of the water equivalent of snow cover and of liquid precipitation during the period of snow melt ;

Calculation of snow melt intensity ;

Determination of losses of snow melt and rain water in period of floods ;

The processes and methods of computation of maximum discharge of snow melt floods in cases—

(*a*) of absence of insufficiency of hydrological data ;

(*b*) of availability of hydrological data.

(III) Influence of the Basin Characteristics on the Elements of Flood Hydrographs:

Influence of the geomorphological, morphometrical and physical and geographical characteristics ;

Surface of the basin, length and gradient of the river, the shape of the basin ;

Influence of the other physiographical characteristics, relief, soil, the presence of forests, lake etc.

(IV) Investigations Aimed at Improving the Precision of Determination of Maximum Discharge

Determination of maximum discharge especially at gauging sections in large flood plains :

Methods of determination of the value of maximum discharge based on high water marks (left by past floods) and the process of evaluation of the probability that these high water levels may be exceeded.

For further details reference may be made to Dr. V. A. Ouryvaeyv, Chairman of the USSR Organizing Committee of the Symposium of Floods and their computation, State Hydrological Institute, V. O. Leningrad, V-53-USSR.

* * *

FIFTH INTERNATIONAL CONFERENCE OF ENGINEERS, ATHENS,

May 7-12, 1967

The 5th International Conference of Engineers will be held in Athens, Greece, from May 7—12, 1967. The theme of the Conference is "The Engineer and Social and Economic Progress" and the Conference will consider the present-day problems of the European Engineer. The four main topics to be considered are :—

1. The Engineer, creator of scientific and technical progress—his place in relation to the pure scientist in the field of research and development.
2. The engineer, creator of economic expansion—his role in the exploitation of scientific and technological discoveries.
3. The education of the Engineer to enable him to meet his scientific and technical responsibilities—his education and training, initially and throughout his career.
4. The Engineer, creator of social progress—his role in urban development.

Further details can be obtained from FEANI Vth Congress Organizing Committee, 4 Karageorgi Street, P. O. Box 673, Athens, Greece.

* * *

IFAC SYMPOSIUM ON "The Problems of Identification in Automatic Control Systems", Prague

June 12—17, 1967

The Institute of Information, Theory and Automaton of the Czechoslovak Academy of Sciences will hold a Symposium on 'The Problems of Identification in Automatic Control Systems' in Prague from June 12—15, 1967. The scientific and technical programme of the Symposium includes the following topics :—

1. Fundamental mathematical problems.
2. The mathematico-physical analysis of the dynamic characteristics of systems.
3. Statistical methods of identification and process parameter estimation.
4. Identification of the dynamic characteristics of systems through the evaluation of determined signals.
5. Identification of systems by means of adaptive models.
6. Special instruments for identification and process parameter estimation.

Further details can be obtained from the Organizing Committee of the IFAC Symposium, Czechoslovak Academy of Sciences, Institute of Information Theory and Automation, Vysehardska 49, Prague 2, Czechoslovakia.

ACOUSTIC NOISE AND ITS CONTROL CONFERENCE, LONDON

January 23—26, 1967

A Conference on "Acoustic Noise and its Control" will be held at the Institution of Electrical Engineers, London, from January 23—26, 1967. Topics to be discussed will include the subjective aspects of noise problems, the nature of the human perception of noise, and the analysis and measurement of noise. Consideration will be given to the ways in which noise is generated in machines and the techniques that are necessary to reduce it to acceptable levels. Methods of reducing internally the noise generated inside a building and methods of impeding its transmission through the structure will also be discussed.

Registration forms and further details are available from the Joint Conference Secretariat, the Institution of Electrical Engineers, Savoy Place, London, W.C. 2.

* * *

AIR TRAFFIC CONTROL SYSTEMS

Engineering and Design Conference, London March 13—17, 1967

The Institution of Electrical Engineers will hold a Conference on "Air Traffic Control Systems, Engineering and Design" in London from March 13—17, 1967. Sponsored by the professional group on Radio Navigation and Radio Location of the IEE Electronics Division and the Radar and Navigational Aids Group of the Institution of Electronic and Radio Engineers, the Conference will cover :—

(*i*) Information Services, *viz.*, Communications for air traffic control, Navigational aids for air traffic control, Primary radar systems and equipment, and Secondary radar systems and equipment ; and

(*ii*) Data Handling and Displays, *viz.*, Display for air traffic control, Methods of character production and presentation, Tracking systems and automatic tracking, Transmission and storage of radar information, and the role of the computer in air traffic control. The Organizing Committee invite the submission of contributions for consideration for inclusion in the conference programme.

Further details will be available from the Joint Conference Secretariat, The Institution of Electrical Engineers, Savoy Place, London, W.C. 2.

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INTERNATIONAL SYMPOSIUM ON

"Modern Optics", New York City March 22—24, 1967

An international Symposium on "Modern Optics" will be held in New York City from March 22—24, 1967. Seventeenth in the series of annual international symposia organized by the Polytechnic Institute of Brooklyn, this Symposium will coincide with the 1967 International Convention of the Institute of Electrical and Electronic Engineers, U.S.A.

This Symposium will propose to map out the domain of this new science. The laser has brought a host of investigations in nonlinear optical properties of materials within the range of experiment. Emphasis should fall on areas such as holography, spatial filtering, information processing, and electrodynamic measurements in which several novel aspects, physical and theoretical, converge. In the tradition of past symposia, this meeting will provide a review of the present status of

modern optics as well as a forum for discussion of the latest advances of interest to engineers and physicists.

Among the more prominent features to be explored in consecutive sessions during the symposium are :—

(*i*) Electro-dynamics—Coherence, Diffraction ;

(*ii*) Information Processing Spatial filtering, Communications ;

(*iii*) Nonlinear Effects—Modulation and Detection, Optical Properties of Materials ;

(*iv*) Optical Instruments—Lasers, Photographic Techniques, Accustic and other Gratings, Zone-Plate Optics, Lens Applications, Moire Effects ; and

(*v*) Holography—Single Colour, Chromatic.

Further details can be obtained from the Secretary, Symposium Committee, Polytechnic Institute of Brooklyn, 333 Jay Street, Brooklyn, New York 11201, U.S.A.

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INTERNATIONAL CONFERENCE ON

"Water for Peace", Washington May 23—31, 1967

An International Conference on "Water for Peace" will be held in Washington from May 23—31, 1967. The Conference will be a forum for the discussion of the water problems of all peoples and all nations. The agenda includes discussions on ministerial and expert levels and has been broadly divided as follows :—

Ministerial Level

1. Planning and Economics of Rural, Urban and Industrial Water Supply.

2. Basic Data Needed for the Planning and Management of Water.

3. Technology : Present Capabilities and Future Prospects.

4. Education and Training.

5. Organizations, Institutions, and Finance.

Expert Level

6. Technology and Research Needs in Water Programmes.

7. Basic Data for Water Programmes.

8. Organizing for Water Programmes.

9. Education and Training in Water Programmes.

10. Planning and Developing Water Programmes.

11. Economics and Finance of Water Programmes.

12. Further information can be obtained from the office of the Secretary-General, Mr. R. C. Hagar, Room, 1316, Department of State, Washington, D.C., 20520, U.S.A.

* * *

SYMPOSIUM ON

"Research in Weather-Tight Joints for Walls", Oslo

Autumn 1967

A Symposium on "Research in Weather-Tight Joints for Walls" will be held in Oslo, Norway, in the autumn of 1967. It is being organized by the Norwegian Building Research Institute on behalf of the International Council for Building Research, Studies and Documentation (CIB). The meeting will discuss problems concerning the design and development of completely weather-proof joints and jointing materials for walls. The symposium will also consider mechanism of rain penetration and aerodynamics as these affect the design and behaviour of joints and joining materials, the effect of movement in building and necessary tolerances. Practical

experiences in jointing and in the use of jointing materials, as well as in related research, testing and development will also be presented, and those interested in doing so are invited to make proposals to the symposium organisers.

Further details can be obtained from the Director, Norwegian Building Research Institute, Post Box 322, OSLO Blindern, Norway or, The General Secretariat of CIB, Weena 700, P.O. Box 299, Rotterdam, The Netherlands.

* * *

SECOND IFAC SYMPOSIUM ON

"Automatic Control in Space", Vienna September 4—8, 1967

The second IFAC Symposium on "Automatic Control in Space" will be held in Vienna, Austria, from September 4—8, 1967. This Symposium is being organized by the IFAC Committee on Space on the invitation of the Austrian Committee on Automaton.

In pursuance of the aims of the first symposium at Stavanger (Norway) the following topics for original papers are proposed :

Space

Booster control. Guidance. Altitude control. Control with man in the loop. Propulsion system control. Navigation. Nionics Applications, including navigation. Optimal trajectory determination, both orbital and interplanetry. Control of landing, on both solid surfaces and water. Automatic exploration systems. Medical monitoring and control. Digital computers applied to control problems.

Underwater

Control of movement of undersea vehicles : submersion, cruising, and on the bottom. Control of hydraulic resistance (including bionics, *e.g.*, movement of fish). Navigation. Propulsion control (including bionics). Propulsion, control, including nuclear. Medical monitoring and control.

Underground

Control during penetration. Remote investigation of underground phenomena, including telemetering.

Emphasis will be laid on application to actual space problems and technical realization. Review papers on Automatic Control in specific systems and for tutorial sessions are also expected.

Authors willing to offer papers to one or more of the above-mentioned topics should send abstracts to Vienna observing the following items :—

(*i*) The abstracts should be submitted in 5 copies not later than October 15, 1966 ;

(*ii*) The abstracts should not cover more than three pages (500-1,000 words) of typewritten text and should contain : Complete title of the paper with reference to the above-mentioned topics, a short formulation of the problems treated, methods for solution and results, and full name of the author, titles and position, private and/or professional addresses ; and

(*iii*) All abstracts should be written in English or Russian (for Russian abstracts English translations are required).

Further details can be obtained from Austrian Productivity Centre, Committee on Automation, POB 131, A-1014 Vienna, Austria.

EIGHTH CONGRESS

Of the International Association for Bridge and Structural Engineering, New York

September 9—14, 1968

The next Congress of the International Association for Bridge and Structural Engineering (IABSE) will be held in New York from September 9 to 14, 1968. The themes of the Congress are given below :—

1. Safety—
   (*i*) Critical appraisal of safety criteria and their basic concepts ;
   (*ii*) Combination of the theories of elasticity, plasticity and viscosity in studying the safety of structure ; and
   (*iii*) Optimization of structures.
2. Thin-Walled Structures—
   (*i*) Theoretical solutions and test-results ;
   (*ii*) Light-gauges cold formed structures ; and
   (*iii*) Thin-walled deep plate girders.
3. Tall Multistorey Buildings—
   (*i*) Plastic design ;
   (*ii*) Column-free box-type framing with and without cone ; and
   (*iii*) Dynamic effects of wind and earthquake.
4. New Practices in Concrete Structures—
   (*i*) New trends in design and construction of long span bridges and viaducts (skew, flat slabs, torsion box) ; and
   (*ii*) Partially prestressed members.
5. New Practices in Concrete Buildings—
   (*i*) Special Problems of tall buildings (spear walls, stability of columns, effect of thermal gradients, construction problems) ;
   (*ii*) Structural lightweight aggregate concrete (concrete technology, structural design) ; and
   (*iii*) Dynamic behaviour of reinforced and prestressed concrete buildings under horizontal forces and the design of joints (including wind, earthquake, blast effects).
6. Dynamic Stresses—
   Effect of dynamic stresses (in particular earthquakes, explosives, blast, wind) on structures.

Those who wish to present a contribution to the prepared discussion should submit to the General Secretariat of IABSE the title and the summary in quintuplicate by January 31, 1968.

Further information can be obtained from the Secretariat of IABSE, Swiss Federal Institute of Technology, 8006 Zurich, Switzerland.

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FORTHCOMING SYMPOSIA IN INDIA.

SYMPOSIUM ON

'Pore Pressures and Shearing Resistance of Soils', Bangalore

September 1967

The object of the Symposium is to assemble, summarize and discuss the present state of knowledge on those aspects of strength of soils that are relevant to the analysis of stability of slopes (natural or artificial, cutting or embankment) and their formations. The Symposium will be of topical interest to engineers engaged in the design and construction of earth dams, dykes, breakwaters, or excavation of canals, highways and railways.

Further details can be obtained from Shri R. Datye, Superintending Engineer, Deccan Irrigation Construction Circle I, Government of Maharashtra, Nasik, or, Prof. B. V. Ranganatham, Civil and Hydraulic Engineering Department, Indian Institute of Science, Bangalore 12.

SEMINAR ON

'Battery Powered Vehicles,' Calcutta November 23, 1966

The primary object of the Seminar was to present to Indian manufacturers, entrepreneurs, engineers and all interested in the field of transport, the latest developments that had taken place abroad. A preliminary study carried out by the Centre had shown that the electric car had great potential in India and in fact recent developments in the U.K. and U.S.A. indicate that India was the most ideal country to start any large-scale venture in this field.

Further details may be obtained from the Indian Lead Zinc Information Centre, 5A Lord Sinha Road, Calcutta 16.

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SYMPOSIUM ON

"Site Investigation for Foundation", Roorkee March 6—8, 1967

The details about the Symposium can be obtained from the Central Building Research Institute, Roorkee, U.P.

Continued from page 90

by silicon cells with an efficiency of 10 per cent costs from 50 to 100 thousand dollars. Because of the high cost, silicon cells are used only in those instances where there is no alternative power source.

If a panel of 30×40 ft. can be made of silicon solar cells, it will produce 12.5 kw. of energy in space where there is not much diffusion of the energy. It is expected that some future space flights may require four panels of about 5000 square feet in area, so as to produce 50 kw. of electrical output.

The weight power ratio is improving markedly. The solar power plant for Mariner II, launched in August 1962, weighed 200 pounds per kilowatt. The ratio for Mariner IV, November, 1964, was 100 pounds per kw. The expected ratio for the panel to be built by Boeing is 50 pounds per kw.

News and Notes

Hamdard Medical Digest, a Journal of the Institute of Health of Tibbi Research, has issued a special number, July to November 1966, Volume X, which contains the biographical sketches of 23 scientists of Pakistan engaged on exploring the unknown depth of scientific knowledge in the country. Besides the biographical sketches, a specimen of their contributions is also printed. The special number, comprising 180 pages, is the first publication which has published biographical sketches of a few scientists of the country in a single volume. It is a useful piece of information and we are sure will be liked by all scientific and research workers of the country.

The scientists and their contributions, besides a few commendable remarks by the President of Pakistan delivered on March 25, 1964, at the Sixteenth All-Pakistan Science Conference, Lyallpur are listed below:

Field-Marshal Mohammad Ayub Khan,
Role of Science Today.

Afridi, Col. M. K.,
Malaria—An inveterate enemy of man.

Ahmad, Dr. Majeed,
Darwinism.

Ahmad, Dr. Nazir,
Effects of High Water Table on the yield of Sugar Cane and Cotton Crops.

Ahmad, Dr. Kazi Said-ud-Din.
Some Geographical Aspects of the Indus Water Treaty and Development of Irrigation in West Pakistan.

Chaudhari, Dr. S. D.,
Scientific and Technical Manpower in Relation to Agricultural Development in Pakistan.

Hedayetullah, Dr. S.,
Culture and Propagation of Rauwolfia Serpentina, Benth, in East Pakistan.

Hussain, Prof. Mian Afzal,
Al-Quran and Modern Science.

Kamal, Dr. Ahmad,
Radiolytic Degradation of Aqueous Cytosine.

Karim, Prof. A. Q. M. B.,
Role of Cultural Scientists in the Development of the Country.

Karim Ullah, Dr.,
Chemist in the Service of Community.

Khan, Dr. Shams-ul-Islam,
Cytogenetic Improvement of Wheat.

Khundkar, Dr. Mukarram Hussain,
Carbohydrates in Human Health and Disease.

Naqvi, Syed Sibte Nabi,
Orign of the Universe and the Man—The Quranic Concept.

Qadri, Dr. Mohammad Afzal Hussain,
Natural History of East Pakistan.

Qudrat-i-Khuda, Dr. Muhammad,
Medicinal Plants in East Pakistan.

Qureshi, Dr. Mazhar Mahmood,
A Survey on Measurements of Activation Energy of Flow in Liquids and their Significance.

Salam, Prof. Abdus,
Elementary Particles.

Siddiqi, Dr. Mohammad Shafqat Hussain,
Scientific and Industrial Research in Pakistan.

Siddiqui, Dr. M. Razi-ud-Din,
Scientific Research in the East.

Siddiqui, Dr. Salimuzzaman,
Chemical Examination of Root Bark of Alangium Lamarckh Thwaites.

Usmani, Dr. I. H.
Science for Survival.

Warsi, Dr. S. A.
Plant Resources of West Pakistan in the Service of National Economy.

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SEATO GRADUATE SCHOOL OF ENGINEERING

The SEATO Graduate School of Engineering provides advanced engineering training of the highest standard leading to the degree of Master of Engineering and research by students, faculty and staff members.

The School was established to help meet the growing need for advance engineering education in Southeast Asia. In Bangkok, studies can be illustrated towards the solution of problems existing in the region. The School was established in July 1959 by a Royal Degree of the Thai Government. The major field of studies were Hydraulic Engineering, Structural Engineering and recently Soil Engineering. The first graduates from the School received their diplomas from the Prime Minister of Thailand in March 1961. The School possesses extensive laboratory facilities, an up to date library and most efficient and well known teachers. Recently a catalogue has been issued by the School. It gives complete information with regard to the mode of admission, courses of studies and expenditure.

Recently the School has issued a summary of the research conducted during the last five years of its existence. The research summary contains useful information with regard to the Projects connected on Hydraulic, Transportation, Structure, Public Health and Soil Engineering Research etc. Very useful information is contained in the summary.

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UTILIZATION OF SOLAR ENERGY

Professor U. Arifov of the Institute of Physics and Technology, Samarkand and Academician of Usbekstan, Academy of Sciences, U.S.S.R. delivered a lecture in New Delhi, on the utilization of the Solar Energy.

Prof. Arifov stated that the major source of energy has been the chemical energy stored in coal and natural gas and used in thermal power station. Hydroelectric power

is another major source of power supply. While the use of atomic energy for electric power production has come in recently, some other sources of energy such as Wind, Sun and Light have remained untapped so far. As compared to Nuclear Engineering, Research in Solar Energy has been neglected. It was stressed that more scientists should take interest in the problem of Solar Energy Utilization.

The efficiency of silicon solar cells has been steadily increasing to the point that it is reported to be 15 per cent. With concentrated solar energy, the figure has been pushed up further. However, at present a solar cell power plant is very expensive. With the use of cadmium sulphide, the power output per unit area has been increased. Search for new semi-conducting materials is continuing so as to reduce the cost. The use of alloys of silicon and germanium in thermo-electric converters has made it possible to operate the hot junction at 1000 degree C and slightly above. But it leaves much to be desired on account of deterioration, oxidation, and poisoning. In this connection the author referred to the work carried out at the Power Institute in Soviet Russia on tellurium compounds, particularly the ones prepared from tellurium, bismuth, and antimony. The control of their properties is proving to be an extremely difficult problem. When perfected, thermoelectric conversion systems may be used for refrigeration and air-conditioning units with low power consumption.

The operation of cesium vapor at 1000°C or so with concentrated solar radiation, at 10 to 15 per cent efficiency, in a diode converter, was also referred by Prof. Arefov.

For obtaining high temperatures, parabolic mirrors of high optical precision are required. He referred to the solar furnace built by Felix Trombe at Mont Louis in the French Pyrenees. The use of parabolic mirrors of very high accuracy for heating purposes resulted in increased cost. This suggested the development of light-weight, low-cost concentrators. He gave details of the process being followed in U.S.S.R. for the production of mirrors made of cement asbestos, whose inside surface is coated with aluminium by evaporation methods. Mirrors 5 to 10 meters in diameter have been successfully prepared. The use of other metals is also being investigated. This has enabled the cost to be reduced by a factor of a hundred.

Utilization of solar energy for drying fruits and vegetables, heating water and air, and distilling water conducted in U.S.A., Japan and other countries was described. He spoke about the use of solar energy in drying fruits and vegetables, and water heaters in the Southern States of U.S.S.R. It has been possible to supply hot water at 60°C from solar water heaters operating at 50 to 60 per cent efficiency for ten to twelve months of the year.

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SIZE AND WEIGHT OF SILICON ELECTRIC CELL

Silicon photovaltic device is the best process which directly transforms radiant energy into electric power. At present time, silicon cells are extensively used in space technology for powering on-board apparatus. The one substantial obstacle for the introduction of these elements for more extensive use for producing power, but which in time will be overcome, is the high cost. In the United States, one cubic centimeter of silicon for a photo-element costs 2 to 5 dollars. Thus the cost of one kilowatt of power produced

(*Continued on page* 87)

Interhom

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A Pakistani Construction and Engineering Firm with a Difference

We believe that we are the only Pakistani Company, who are successfully handling construction of civil, electrical, mechanical and communication projects on turnkey basis. The following sampling will indicate the range of our activities:

Construction of Pakistan Government future Secretariat at Islamabad. It is a big complex of eight multi-storey blocks and various auxiliary works and buildings. The project is scheduled to be completed by early 1967.

Construction of second phase of Pakistan Institute of Nuclear Science and Technology.

Installation of a 132 KV indoor type grid Sub-station at Korangi for Karachi Electric Supply Corporation. (Completed March 1966).

Supply and installation supervision of H.F./V.H.F. network in East Pakistan (Under installation).

Supply, erection and commissioning on turnkey basis of 500 miles of power transmission lines and 50 pole mounted Sub-stations in districts of Bahawalpur, Rahimyar Khan, Multan, Lyallpur (Completed in July 1965).

Supply, erection and commissioning of distribution network at 66/33/11KV in Quetta area and installation of four 66/11 KV Sub-Stations (completed in September, 1964.

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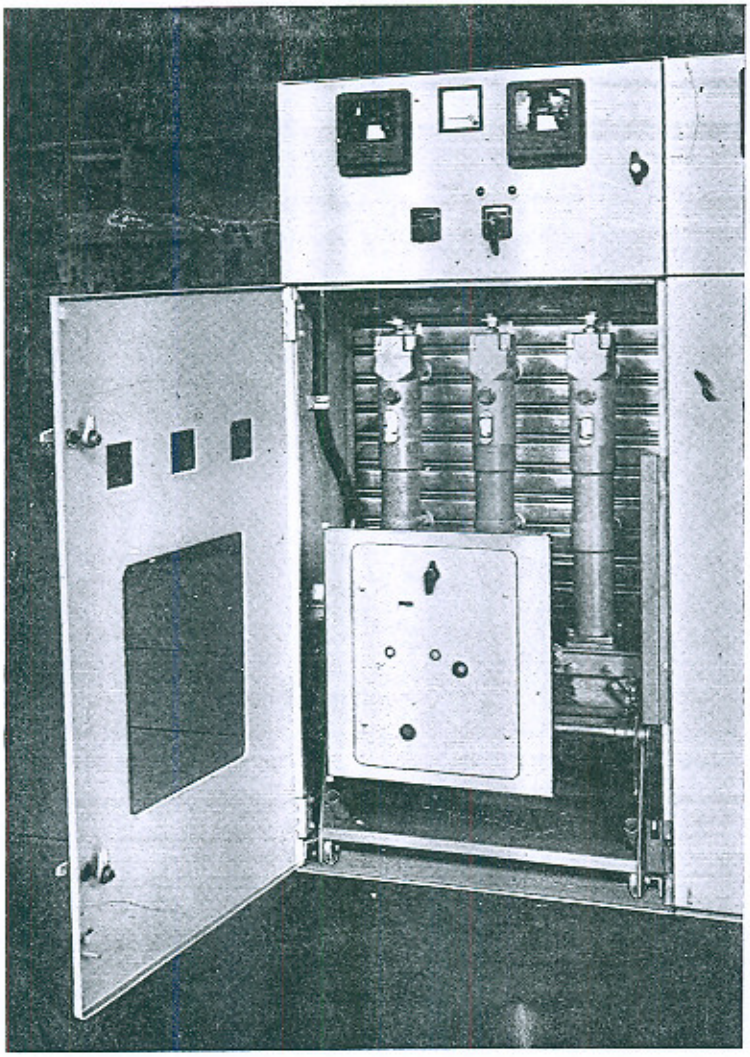

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