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THE NEW IRRIGATION ERA

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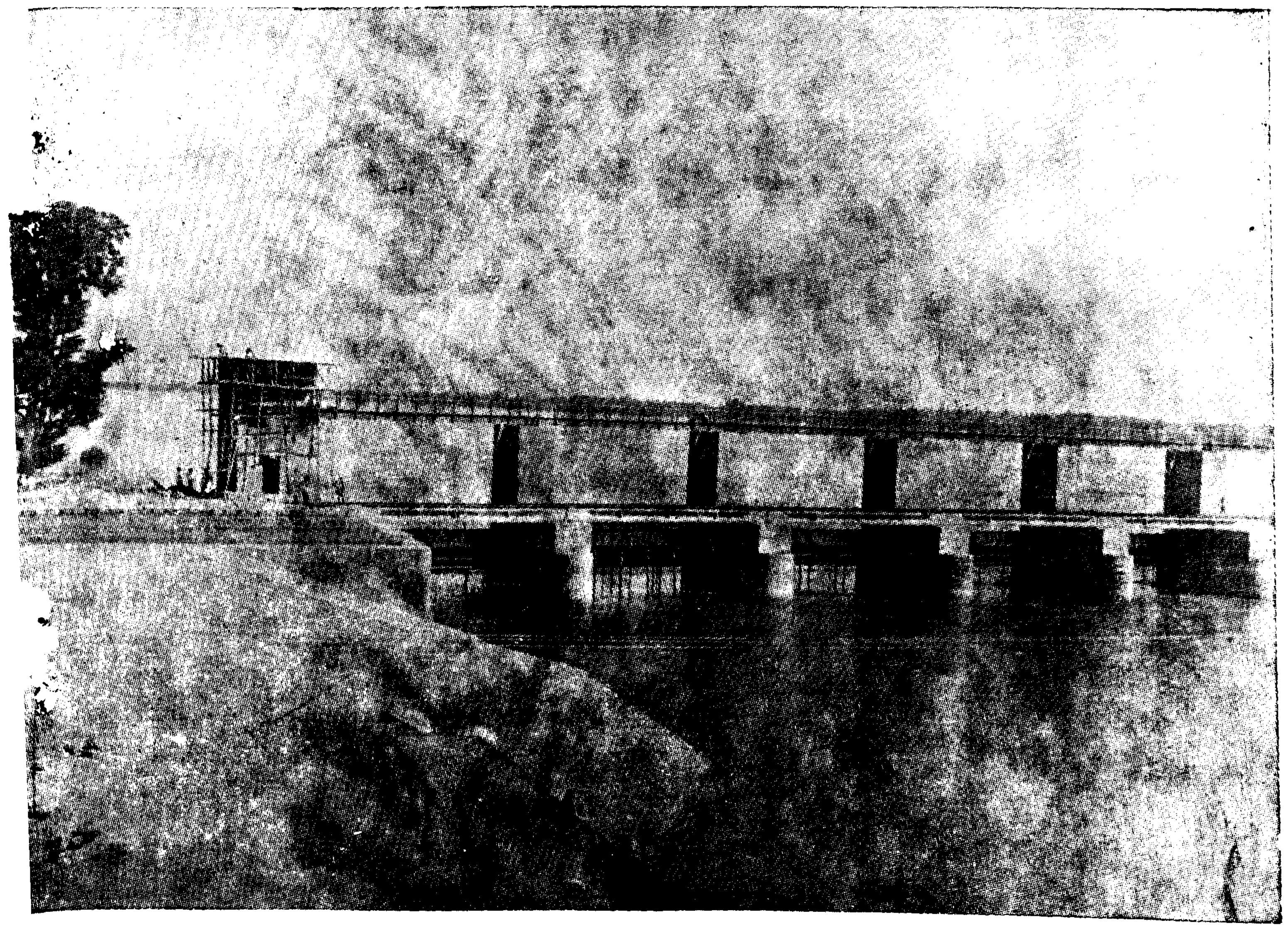
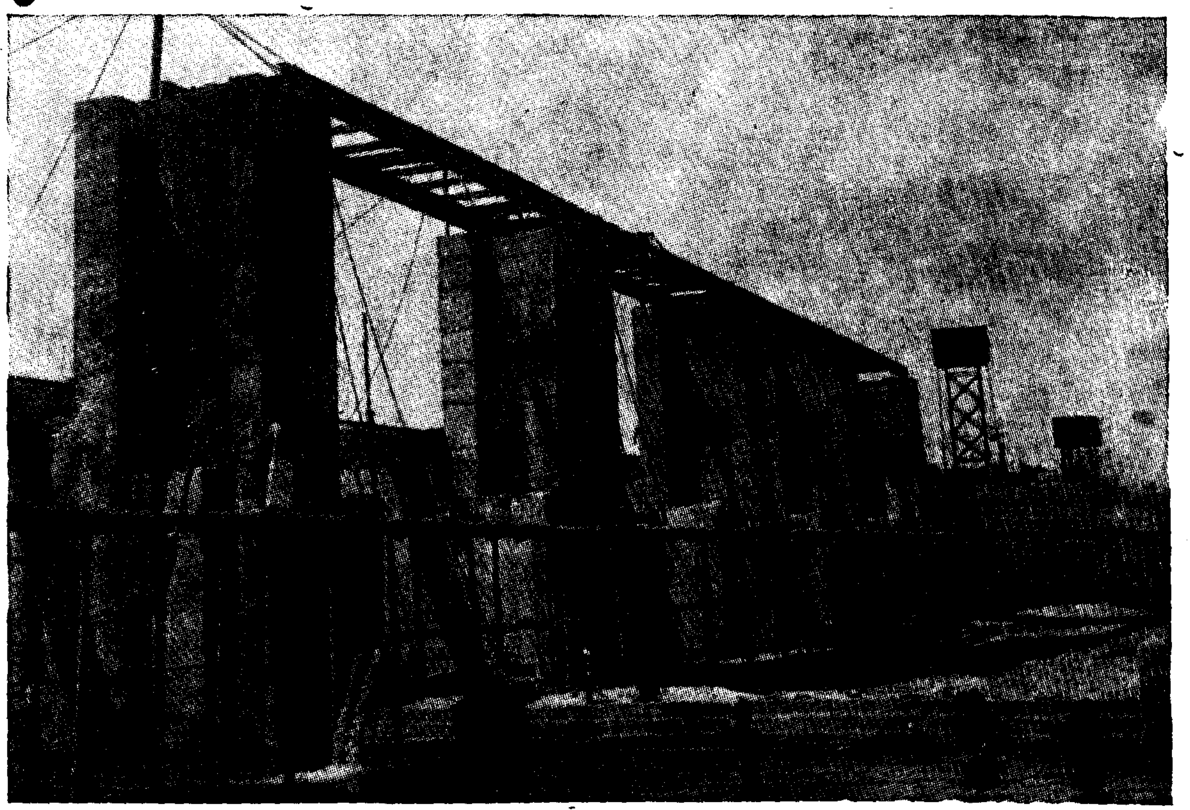


Barrage across Cauvery at upper Anicut.

Secretary to Government P.W.D. and the Chief Engineer (Irrigation) at upper Anicut.



A View of the Barrage Across Cauvery at upper Anicut.

THE NEW IRRIGATION ERA

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EDITORIAL

Inter-basin transfers of water for Irrigation is a subject thought of now-a-days since many of the regions in India are affected by drought every year, due to failure of monsoons, whereas there are some areas of surplus water potential. There are already some inter-basin transfers of minor nature like the diversion of Periyar and Parambikulam to the east. But the most important link will be from Ganga to the Cauvery connecting the major river basins of Narmadah, Godavari and Krishna enroute. This and other inter-basin transfers like Brahmaputra—Ganga, Chembal across the Aravalli mountains were detailed in the first article which is a resume of the lecture given by Dr. K. L. Rao, former Union Minister for Irrigation and Power.

Rainfall being the main source of surface and ground water, collection of rainfall particulars from some of the rainfall stations of Tamil Nadu, checking this data for homogenity and for filling up missing data is very important. The monthly rainfall data during a selected period for twenty selected key stations were picked out for the simulation of the missing rainfall data. This has been enunciated by Thiru S. Panchanathan, Chief Engineer, P.W.D., Ground Water, Tamil Nadu.

In recent times a number of dams have been constructed in Tamil Nadu. The special feature of these dams are adoption of masonry-*cum*-earth dams. To study the structural behaviour during and after construction, instruments are installed in different sections of the dams. The data obtained from such instruments installed are highly useful for indicating the dynamic behaviour of the structure under stresses developed during construction or during the operation of the dam. Also these studies are useful in correlating the results obtained in model studies. This is dealt with in detail in the third article.

Under "Courtesy from THE HINDU" an article named Better Management of Water Resources has been published.

In the last article the author Thiru M. Sadasivam, Assistant Professor of Civil Engineering, Guindy has explained about the science of photogrammetry. Photogrammetry is only an art of obtaining reliable measurements from Photographs. If it is qualitative, it is called Photographic interpretation and if it is quantitative, it is called photogrammetry. Major application of this is in Military sphere both for defence tactics and offence manoeuvres. Photogrammetry has also helped Medicine, Criminology motion studies, astronomy, Architecture, hydraulic and teaching.

In conclusion may we request all Engineers of Tamil Nadu Public Works Department and other departments to come forward with articles for the future issues of the journal and serve the common cause of the Engineers of the State.

———

GANGA FOR DROUGHT AREAS

By

*Dr. K. L. Rao.

1. *Drought areas in the country.*

In India one-third of the land that is cultivated is subjected to drought conditions. The drought areas possess every year an expenditure of unknown quantum. The main reason for India's inability to produce foodgrains commensurate with the land cultivated is the specially unfavourable features of rainfall. If the rainfall is less than 75 per cent of the normal in an area and this occurs in 20 per cent of the years, the area is considered as a drought area. It may be seen that the total number of districts prone to drought are about one-fourth of the total districts in the country. Statistical reports show that India's total food production inspite of the vast area under cultivation, is far less than the other countries like the U.S.S.R. and China where similar extent of areas are cultivated. The main reasons are the large areas of drought where no water is available resulting in insecure farming with poor results.

2. *Water resources for the drought area.*

We have 14 major rivers, 44 medium rivers and numerous minor rivers in the country. It may be seen that of all the water resources the Ganga basin only can contribute as the main source of interbasin transfer. The main areas where water is inadequate are the region on the north of Tapi and the peninsular area excepting for Mahanadhi river region. The above regions have got to be fed by the inter-basin transfer. Fifty per cent of the drought areas of the country are located in this region.

3. *Necessity for inter-basin transfer.*

In the river Ganga, the entire quantity of water up to Patna is utilised by Uttar Pradesh and Madhya Pradesh. Surplus water is available only beyond Patna. It is seen that surplus water is located at a corner of the Ganga basin while the drought areas are all located in the western portion of India, where more than half of India's cultivated land is located. Thus while the surplus waters of the Ganga are flowing to the east, the requirement is in the west. The inter-basin transfer is therefore inevitable.

4. *Description of Ganga and Godavari rivers.*

The main contributors of water for the National water link are the Ganga and Godavari rivers. Some of the salient features of these two are worth mentioning here.

The total length of the river Ganga is 2,525 km. of which 1,400 km. is in Uttar Pradesh, 445 km. in Bihar and 525 km. in West Bengal. The basin area is slightly more than one fourth of India's geographical area and the total annual flow in Ganga is nearly 500 thousand million cubic metre. It may be seen that this basin has the largest gross sown area of nearly 58 million hectares

The second largest and useful river in India is Godavari. About 16 million hectares of land is irrigated in this basin. The flow in the river is 105 T. M. C M, about 1/5th of the flow in Ganga.

5. *The National Water Links*

By linking the various rivers it is possible to break the severity of the condition in the drought area and it will help to overcome the difficulties due to variation of the rainfall in any particular area and year. The imbalance of the regional water resources can be rectified to an extent. Few such important links are discussed here.

The most important link is from the Ganga to the Cauvery in the South passing enroute and connecting the major river basins of the sone, Narmada, Tapi, Godavari, Krishna, Pennar, etc. Excess water can be pumped from the Ganga into the link canal at Patna. Starting at Patna at 45 metres elevation, the water has to be lifted upto 300 metres in stages. The maximum available diversion may be 1,700 cumec. in the present studies. It is also expected that it will be possible to pump this water for half the year. Water from Ganga can be pumped to the Narmada and then through Weinganga, Godavari, then to Krishna, the Pennar and to the Cauvery upstream of the Upper Anicut. Storages will have to be constructed to consume and supply according to the requirements.

The next link is Brahmaputra Ganga. Bhramaputra carries a discharge of 5,000 cumec. even during the dry summer month. This is considerably higher than the requirement of the basin itself. A barrage at Dhubrie and a canal of about 300 km. can take the water to Ganga. The possible diversion will be 1,150 cumec. and the lift will be very small ranging from 12 to 15 metres. A portion of the canal will lie in Bangladesh and approval have to be got from the Bangladesh Government.

The next link is the canal from Navgam to Gujarat and Western Rajasthan. Water can be diverted from Navgam on Narmada to serve the area of Kutch and the Western Rajasthan.

Another link can utilise the water of the Chambal across the Aravalli Mountain ranges in Ajmir and Central Rajasthan.

Another link may be to connect all western ghat rivers and to bring it to east. During monsoon period heavy surplus water is wasted into the sea. Parambikulam Aliyar Project is one of the schemes successfully done in this type of inter-basin transfer.

Dr. K. L. Rao, M.P., former Union Minister for Irrigation and Power addressed to the Institution of Engineers (India), Madras, Centre, on 20—12—1975 during a special meeting convened. The topic of the lecture was "Ganga for Drought Areas". A resume of the lecture is given above.

The above discussed links are some of the main links which are now being thought of. Few such inter-basin transfers successfully carried out by U. S. A. and U. S. S. R. are worth mentioning here. In U. S. A. the Columbia water plan was completed and transfer of 5,000 M. cum. over a length of 700 km. involving a lift of 1,200 metres from northern part to southern part of the country has been effected. Similarly, in the U. S. S. R. the Iritis-Kargada Scheme has been completed. The canal is 450 km. with capacity of 75 cumec., lift involving about 20 metres. Both countries are programming for much bigger schemes.

Thus, in the coming decades it is impossible to avoid large inter-basin transfer of water, particularly in India, where there is no choice if starvation is to be avoided to the teeming millions of India.

With the available data in Central Water and Power Commission this proposal was submitted to the United Nation for preliminary examination. During 12/71 and 3/72 United Nation's experts investigated and recommended favourable for the execution of the scheme. They have also seen that the National Watergrid will be a vital necessity for India by the year 2000.

6. *Programme of Investigation* —

The investigation may have to be done to assess the quantities of water. The daily hydrographs at various important points of the main rivers and the distributaries have to be made up for the 14 major rivers. This information is required at the important points of the river and their tributaries. The topographycal surveys of 2 or 3 alternate alignments of the Ganga-Cauvery link and the Brahmaputra-Ganga link are to be done Storage possibilities are to be investigated. If the storage possibilities are large, success of the scheme will be much greater. Investigation regarding the large power requirement and its source of supply etc. have to be made.

7. In conclusion it is emphasised that the countrys' food problem can be solved only by the inter-linking of the rivers. Ganga can solve the basic problems of the country if we make full use of it.

RAINFALL DATA OF TAMIL NADU.

by

*Thiru S. PANCHANATHAN, B.E., (C)., B.E. (H)., M.S. (COLUMBIA), F.I.E (INDIA).

S. Panchanathan

General

Tamil Nadu has an area of 1,30,069 sq. km. As per ISS 4987—1968, the density of raingauge stations should be one in 520 sq. km. for plains, one in 260 sq. km. for moderate hills and one in 130 sq. km. for mountainous regions. Compared with the above norms the distribution of rainfall stations in Tamil Nadu is good. Data is available for most of the stations from 1921 onwards, but with gaps. Also the maintenance of stations is not to the desirable standards. As rain fall is the main source for surface and groundwaters, it was found necessary during the groundwater investigation of the State, to check this data for homogeneity and for filling up of missing data.

Out of the 330 raingauge stations for which data was collected by this department, data of 267 stations as detailed below districtwise, were considered for the study using the computer at I. I. T. Guindy.

District.	*Number of raingauge stations.*	*Number of rainguage stations used for computer study.*
Chenglepattu	28	28
North Arcot	29	29
Dharmapuri	14	14
Salem	14	14
South Arcot	35	35
Tiruchirappalli	24	24
Thanjavur	24	Nil.
Pudukottai	16	14
Nilgiris	37	Nil.
Coimbatore	30	30
Madurai	20	20
Ramanathapuram	23	23
Tirunelveli	20	20
Kanyakumari	16	16
Total ..	330	267

Procedure adopted

Monthly rainfall data from the above 267 stations were copied, punched and verified. Each station record was tested for statistical homogeneity. 189 station records. of varying length passed the test, some of them, however, with only parts of the original records.

An optimum period of concurrent records, 1920–21 to 1969–70 was selected and the following 20 key stations with full records during the selected time period were picked out for the simulation of the missing rainfall data The rainfall data for the 20 key stations is given in Table I.

TABLE I.

1 Vanur	11 Srivilliputhur
2 Kurinjipadi	12 Kadayanallur
3 Mannargudi	13 Arasadi
4 Virudhachalam	14 Srivaikundam
5 Portonovo	15 Kayathar
6 Gobichettipalayam	16 Ambasamudram
7 Thiruppathur	17 Puttandam
8 Theethandatanam	18 Tenkasi
9 Paramakudi	19 Mulakumoodu
10 Sivaganga	20 Pechiparai

All the gaps in the 169 'Secondary' station records between June 1920 and May 1970 were filled in by selecting, month by month the key station which with concurrent records (even outside the selected time period) showed the highest correlation co-efficient, and by using its data for a stochastic simulation of missing data based upon recorded frequency distributions on a semilog scale.

A rainfall data bank was created containing 189 records, each of which was statistically homogenous at the 95 percent level and each of which covered the period 1920–21; 1969–70. The following statistics of each station were worked out :—

(i) Mean;

(ii) Standard deviation;

(iii) Co efficient of variation, for the individual monthly totals as well as for the annual totals; and

(iv) Serial co-rrelation coefficient for the preceding 12 months.

* Chief Engineer, P.W.D. (Ground water).

By employing a method based on randomization of 5 year series of annual totals combined with the determination of the statistical parameters by the maximum likelihood solution, the maximum and minimum annual rainfall with a return period of 2, 5, 20 and 100 years together with their standard errors at the 68 per cent probability level were worked out for each rainfall station.

Analysis of the Results.—It can be seen from the Tables that 33 stations given below record rainfall under 750 mm. which can be considered to be the limits of drought conditions. The stations that have recorded rainfall within drought conditions are :—

1 Arasadi
2 Srivaikundam
3 Kayathar
4 Penkondapuram
5 Paramathi
6 Tiruchengode
7 Tiruppur
8 Perundurai
9 Palladam
10 Sulur
11 Panchapatti
12 Palaviduthi
13 Mayanur
14 Karur
15 Aravakurichi
16 Amaravathinagar
17 Udamalpet
18 Thirumoorthinagar
19 Agricultural College (Coimbatore).
20 Muthukulathur
21 Kamuthi
22 Vilathikulam
23 Sathur
24 Kovilpatti
25 Sankarankoil
26 Tuticorin
27 Tiruchendur
28 Kulasekarapattinam
29 Ottapidaram
30 Sattankulam
31 Palayamkottai
32 Tirunelveli
33 Radhapuram

It is necessary that the areas falling under the influence of these 33 stations are given pointed attention when drawing programmes of development that require water as one of the resources. The area of influence can be fixed by means of Thieseen Polygon. The natural resources within these areas are to be specially protected and development plan that are contemplated to increase regional income to increase regional employment and to improve the economic base should be taken into account this deficiency of rainfall.

With the data of the 189 stations, isohyets have been drawn for Tamil Nadu for the advancing monsoon retrating monsoon and the transitional period in the appended drawings, I, II and III.

TABLE I.

Serial number and station.	*Rainfall Mean (cm.m.)*	*Standard Deviation.*
1 Vanur	1,157	351
2 Kurinjipadi	1,163	324
3 Mannargudi	1,198	306
4 Virudhachalam	1,091	287
5 Portonovo	1,362	412
6 Gobichettipalayam	793	184
7 Thiruppathur	1,033	214
8 Theerthandatanam	897	268
9 Paramakudi	768	222
10 Sivaganga	885	191
11 Srivilliputhur	850	221
12 Kadayanallur	867	255
13 Arasadi	592	185
14 Srivaikuntam	687	231
15 Kayathar	752	184
16 Ambasamudram	991	264
17 Puttandam	1,991	477
18 Tenkasi	1,168	310
19 Mulakumcodu	1,489	365
20 Pechipari	2,059	517

TABLE II.

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Serial number and Station.	*Observed Data.* *Mean (in mm.)*	*Observed Data.* *Standard Deviation.*	*Simulated Data.* *Mean (in mm.)*	*Simulated Data.* *Standard Diviation.*	*All Data.* *Mean (in mm.)*	*All Data.* *Standard Diviation.*
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1 Athipet	1,216	407	1,065	368	1,125	387
2 Chepauk	1,059	239	1,140	363	1,113	326
3 Nungambakkam	1,295	317	1,235	322	1,252	319
4 Saidapet	1,237	341	1,709	453	1,256	353
5 Koratur	993	412	1,111	267	1,054	346
6 Ponneri	1,202	391	1,344	359	1,245	384
7 Red Hills	1,058	406	1,099	378	1,085	385
8 Cholavaram	1,232	574	1,440	380	1,340	489
9 Chembarambakkam	1,079	435	1,193	314	1,138	378
10 Poonamalle	1,250	449	1,158	260	1,213	384
11 Tamarapakkam	1,123	420	1,189	338	1,157	377
12 Sathyavedu	1,219	381	1,226	557	1,222	465
13 Tiruvallur	1,052	291	1,067	156	1,053	283
14 Kesavaram	1,047	361	1,140	271	1,095	318
15 Tiruttani	1,034	391	1,090	394	1,071	390
16 Kovalam	1,386	417	1,342	380	1,365	396
17 Mahabalipuram	1,160	478	1,318	349	1,242	419
18 Meenambakkam	1,143	282	1,264	369	1,225	346
19 Cheyyar	1,310	379	1,159	359	1,238	374
20 Chingleput	1,206	415	1,105	330	1,132	353
21 Sriperumbudur	1,081	276	972	260	1,024	271
22 Madurantakam	1,258	375	1,189	362	1,225	367
23 Markanam	1,189	348	1,085	329	1,179	344
24 Kancheepuram	1,079	284	1,275	0	1,083	282
25 Tindivanam	1,114	299	0	0	1,114	299
26 Panapauk	986	250	1,062	231	1,025	241
27 Vakkadi	1,066	337	1,242	291	1,158	323
28 Gingee	1,083	366	1,223	365	1,120	367
29 Uttiramerur	1,089	206	1,261	0	1,092	304
30 Alliabad aniout	1,088	251	1,123	273	1,107	261
31 Sathanur Project	1,018	276	1,073	241	1,060	248
32 Uttankarai	846	177	871	123	848	173
33 Harur	794	182	880	139	801	179
34 Penukondapuram	702	285	628	237	680	272
35 Barur	769	186	785	177	774	182
36 Nedungal	801	198	784	154	793	177
37 Krishnagiri	827	214	792	221	817	214
38 Dharmapuri	835	167	964	129	845	167
39 Palakodu	942	228	986	209	976	212
40 Rayakotta	768	195	702	201	762	195
41 Marandahalli	843	252	870	199	857	223
42 Pennagaram	854	208	836	211	852	206
43 Hosur	809	183	776	206	805	183
44 Denkanikotta	898	218	824	198	890	215
45 Thally	835	227	890	158	846	214
46 Cuddalore	1,328	403	1,084	0	1,323	400

TABLE II—*cont.*

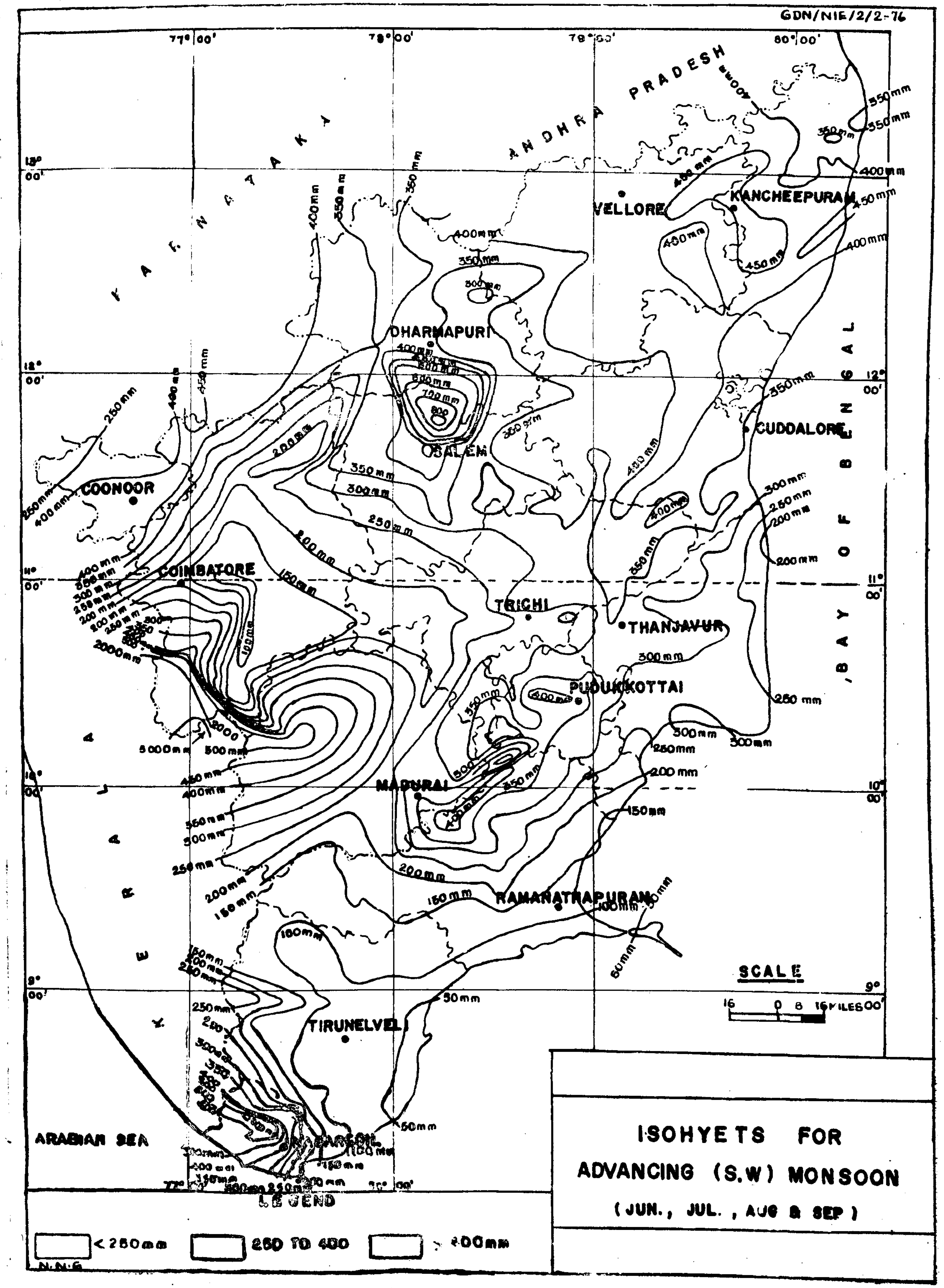
Serial number and Station.	Observed Data.		Simulated Data.		All Data.	
	Mean (in mm).	Standard Deviation.	Mean (in mm).	Standard Deviation.	Mean (in mm).	Standard Deviation.
(1)	(2)	(3)	(4)	(5)	(6)	(7)
47 Vanamadevi	1,026	357	1,181	341	1,106	354
48 Kothavancherri	998	305	1,055	322	1,028	312
49 Panruti	1,162	343	0	0	1,162	343
50 Sathiatope anicut	955	308	1,060	280	1,010	295
51 Villupuram	1,119	278	0	0	1,119	278
52 Srimushnam	1,168	258	1,120	291	1,145	272
53 Vridhachalam anicut	1,011	268	1,164	361	1,090	326
54 Jayamkondam	1,141	390	1,040	212	1,089	311
55 Ulundurpet	1,015	268	0	0	1,015	268
56 Tirukoilur anicut	1,073	355	1,197	341	1,137	350
57 Chidambaram	1,350	335	0	0	1,350	335
58 Mehmattur	1,041	361	1,085	301	1,064	329
59 Tirukoilur	936	259	920	152	933	239
60 Thittakudi	1,098	313	1,107	0	1,098	310
61 Kattumylore	869	328	938	185	905	263
62 Kilacheruvai	998	301	1,074	235	1,037	269
63 Ariyalur	1,102	328	1,090	259	1,096	291
64 Thozhudur	1,054	279	1,097	308	1,076	293
65 Elathur	1,104	348	1,221	333	1,165	342
66 Kallakurichi	989	231	1,098	258	1,017	241
67 Sankarapuram	838	301	881	207	868	237
68 Chettikulam	895	261	943	173	899	254
69 Attur	1,058	197	1,083	266	1,066	219
70 Thuraiyur	897	187	905	183	899	184
71 Uppiliapuram	887	191	1,024	0	890	190
72 Thammapatti	795	194	861	148	816	182
73 Thathayangarpet	876	239	919	178	888	223
74 Vazhapadi	805	172	910	216	813	176
75 Sendamangalam	845	185	859	83	846	178
76 Yercaud	1,620	281	1,644	291	1,634	284
77 Rasipuram	857	154	832	219	855	151
78 Namakkal	768	181	795	129	770	176
79 Salem	959	196	941	110	957	195
80 Omalur	874	220	905	188	883	210
81 Paramathi	681	197	574	58	672	192
82 Thiruchengode	755	187	694	159	750	184
83 Sankari	788	175	661	132	778	174
84 Tiruppur	651	156	0	0	651	156
85 Perundurai	744	203	772	121	750	187
86 Palladam	558	162	625	0	560	160
87 Sathyamangalam	771	219	705	190	766	216
88 Sulur	505	164	0	0	505	164
89 Talavadi	849	148	1,098	567	1,043	514
90 Tiruchirapalli	793	205	944	395	805	223
91 Karambakudi	867	280	1,061	245	883	280
92 Malayur	822	228	824	208	823	211
93 Alangudi	924	205	1,054	259	943	215

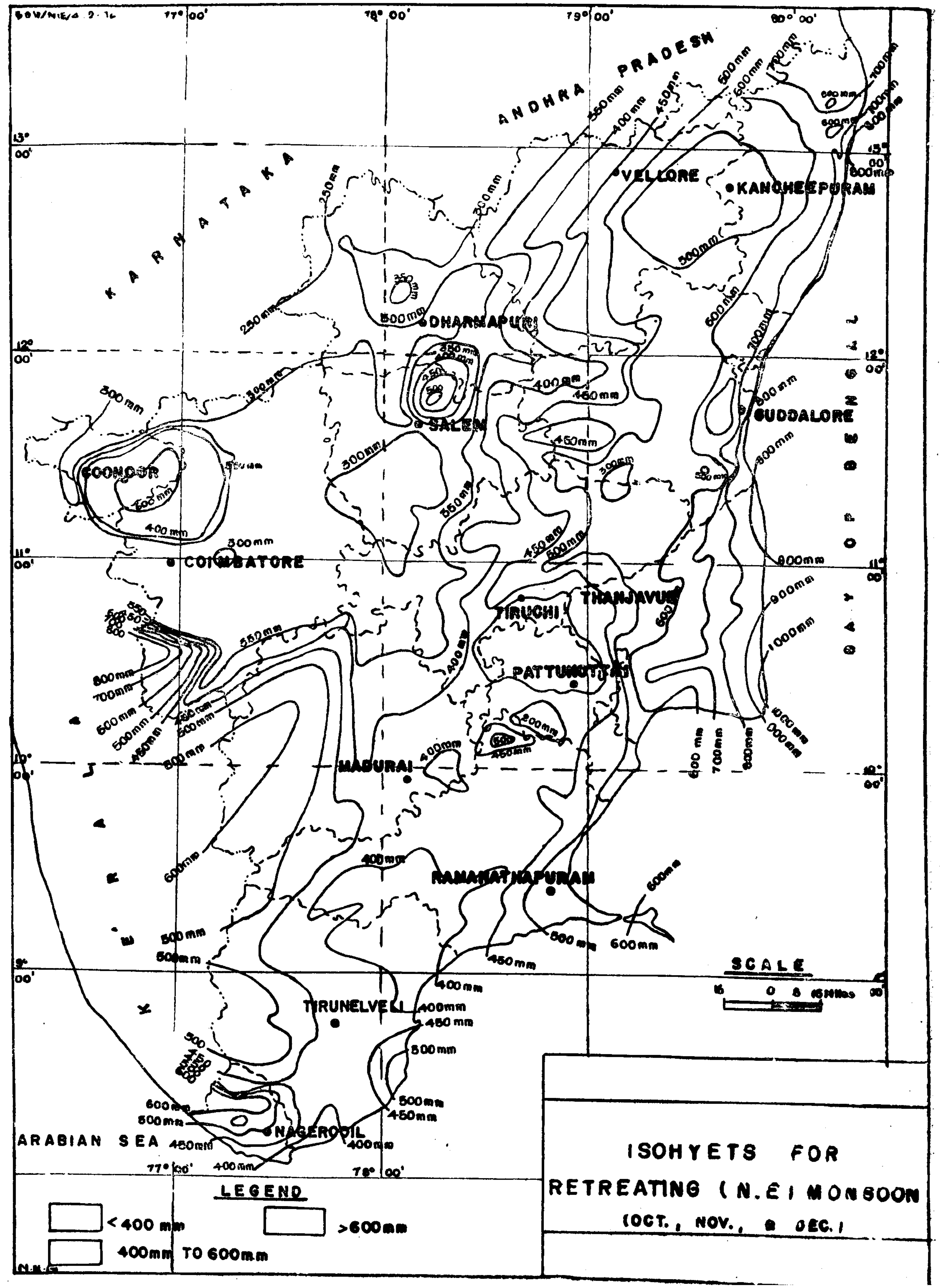
TABLE II—*cont.*

Serial number and Station.	Observed Data.		Simulated Data.		All Data.	
	Mean (in mm.)	Standard Deviation.	Mean (in mm).	Standard Deviation.	Mean (in mm).	Standard Deviation.
(1)	(2)	(3)	(4)	(5)	(6)	(7)
94 Adanakkottai	970	216	879	241	928	236
95 Perungalur	925	438	1,026	284	971	375
96 Pudukkottai	971	180	948	167	966	170
97 Lalgudi	903	259	948	0	904	254
98 Thirumayam	905	189	987	261	912	196
99 Annavasal	935	229	1,028	297	967	255
100 Illuppur	835	220	923	303	859	246
101 Karaiyur	843	271	907	273	879	271
102 Keelanilai	850	291	940	80	855	285
103 Upper Anicut	954	340	1,051	318	974	331
104 Manakudi	959	190	868	273	897	253
105 Viralimalai	791	204	840	216	801	205
106 Ponnamaravadhi	1,055	229	1,104	206	1,058	226
107 Keeranur	882	180	1,072	439	897	210
108 Musiri	766	190	768	184	767	185
109 Manapparai	920	230	792	0	917	228
110 Marungapuri	937	256	1,071	250	945	256
111 Kulithalai	773	196	938	0	776	195
112 Panchapatti	679	191	708	206	695	198
113 Palavidudhi	579	221	621	120	602	190
114 Mayanur	633	203	620	146	626	170
115 Karur	637	184	488	0	634	183
116 Andipatti	857	202	887	155	871	180
117 Cholavandan	841	160	774	189	809	176
118 Aravakkurichi	633	170	799	0	636	170
119 Kodaikanal	1,640	[illegible]	0	0	1,640	319
120 Amaravathinagar	672	213	748	169	725	184
121 Udamalpet	626	195	582	192	614	193
122 Thirumurthynagar	512	298	622	200	602	221
123 Pollachi	910	221	1,115	0	914	220
124 Anamalai	3,449	1,445	3,612	988	3,580	1,080
125 Agricultural College	628	172	468	0	625	171
126 Chinnakallar	3,421	1,345	4,108	1,392	3,985	1,396
127 Pamban	848	291	815	219	841	275
128 Vattanam	817	258	926	203	845	247
129 Thiruvadanai	795	192	844	145	809	180
130 Ramanathapuram	877	218	0	0	877	218
131 Morekulam	769	240	788	262	771	242
132 Muthukulathur	723	187	0	0	723	187
133 Manamadurai	909	341	931	170	914	209
134 Kamuthi	716	197	767	552	718	310
135 Chittampatti	819	257	846	236	833	209
136 Thiruppuvanam	1,013	210	1,075	241	1,059	244
137 Vilathikulam	665	160	648	208	661	233
138 Aruppukottai	810	188	722	209	768	170
139 Virudhunagar	813	218	853	150	823	201
						202

TABLE II—*cont.*

Serial number and Station.	Observed Data.		Simulated Data.		All Data.	
	Mean (in mm).	Standard Deviation.	Mean (in mm.)	Standard Deviation.	Mean (in mm).	Standard Deviation.
(1)	(2)	(3)	(4)	(5)	(6)	(7)
140 Sathur	756	154	654	206	752	155
141 Kovilpatti	727	160	0	0	727	160
142 Sivakasi	776	196	767	161	775	193
143 Watrap	889	278	798	186	867	260
144 Sankarankoil	738	225	683	175	726	214
145 Sivagiri	896	277	0	0	896	277
146 Gudalur	969	360	936	0	959	360
147 Tuticorin	644	272	679	229	670	238
148 Tiruchendur	747	292	0	0	747	292
149 Kulasekarapattinam	724	299	0	0	724	299
150 Ottapidaram	688	182	631	184	658	183
151 Sattankulam	671	243	0	0	671	243
152 Palayamkottai	712	188	695	229	709	195
153 Tirunelveli	730	146	724	193	726	181
154 Radhapuram	734	123	728	232	730	208
155 Nanguneri	781	175	0	0	781	175
156 Kottaram	776	158	828	220	814	206
157 Aralvoimozhi	954	208	1,139	321	1,091	305
158 Nagercoil	1,100	302	1,364	337	1,168	329
159 Thadikarankonam	1,672	417	1,652	351	1,667	400
160 Churalakode	1,722	394	0	0	1,722	394
161 Kadayam	958	297	999	320	975	305
162 Rajakkamangalam	1,030	321	1,149	20	1,061	322
163 Mekode	1,716	349	0	0	1,716	349
164 Thuckalai	1,498	372	1 331	235	1,461	351
165 Eranjel	1.301	288	0	0	1.301	288
166 Kalial	1,834	626	0	0	1,834	626
167 Colachel	1,239	315	1,109	187	1,211	295
168 Seethapal	1,105	292	1,013	266	1,084	286
169 Kuzhithurai	1,444	374	0	0	1,444	374

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PATTUKOTTAI
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RAMANATHAPURAM
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NAGERCOIL
ARABIAN SEA
SCALE
LEGEND
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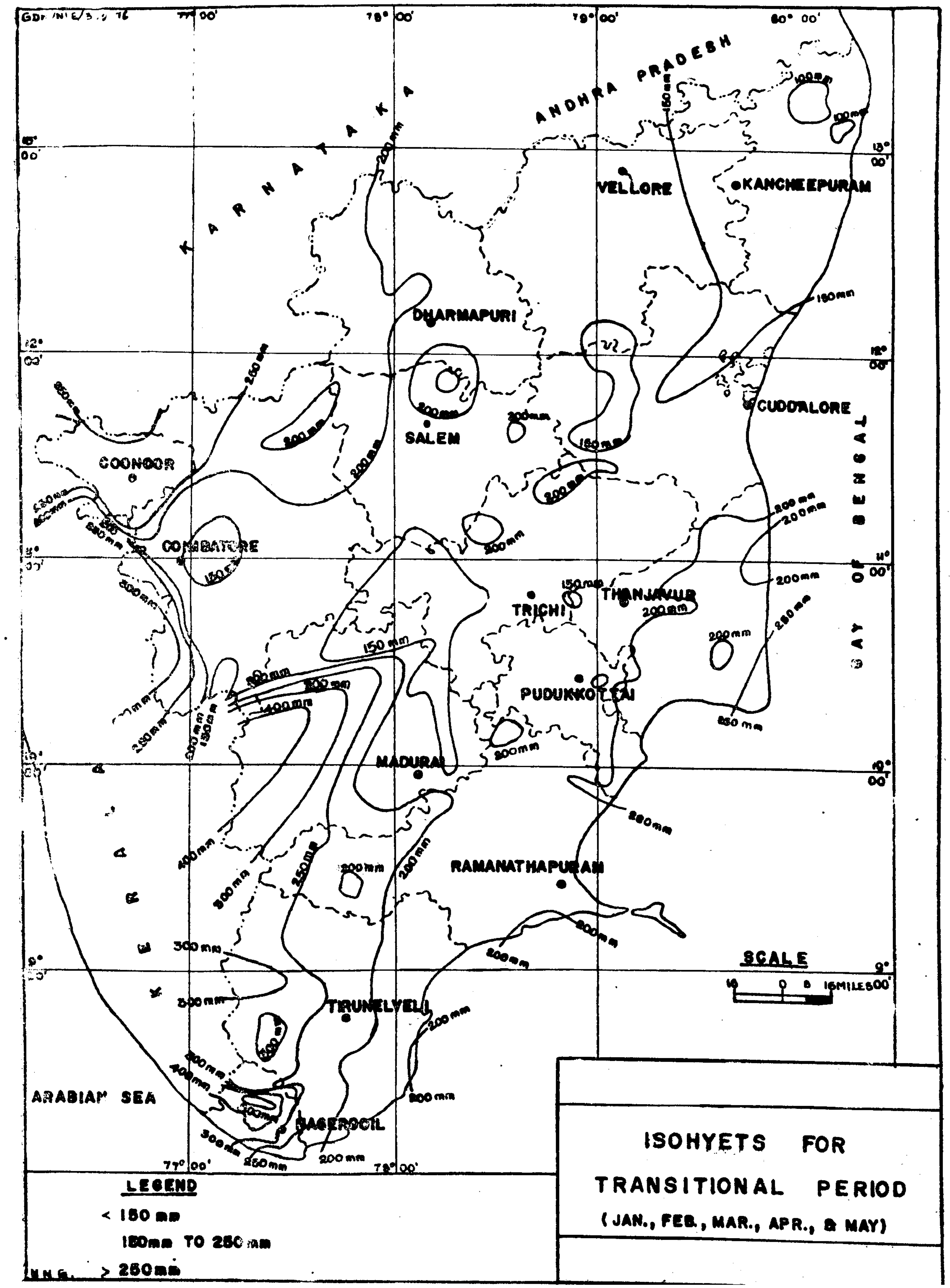
RETREATING (N.E) MONSOON
(OCT., NOV., & DEC.)



ISOHYETS FOR TRANSITIONAL PERIOD

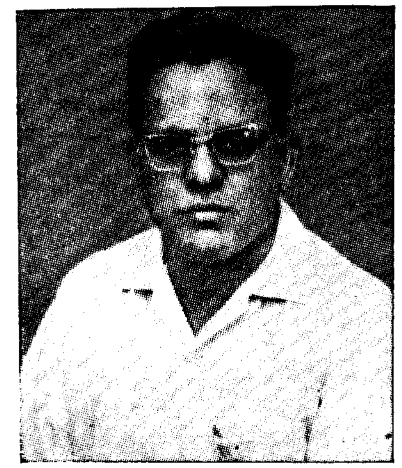
(JAN., FEB., MAR., APR., & MAY)

PROTOTYPE BEHAVIOUR OF HYDRAULIC STRUCTURES IN TAMIL NADU.

A PRELIMINARY STUDY ON THE PROTOTYPE BEHAVIOUR OF A DAM.

BY

1. Thiru A. N. Raju, B.E. *



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1. *Introduction—*

1.1. Dams are generally designed on the basis of theoritical laws and computations based upon the results of test on materials of construction. Due to uncertanities and limitations in the theoritical solutions and in the Engineering tests reliance should be resorted to wherever possible on the experiences gained from a study of the performance of such structures.

1.2. Irrigation through Dams and Anicuts in Tamil Nadu dates back to the second Century A.D. In recent times a number of dams (viz.) Manimuthar, Lower Bhavani, Amaravathy, Vaigai, Sathanur, Krishnagiri, etc. have been completed in Tamil Nadu during the Five-Year Plan periods. The Multi-purpose Parambikulam—Aliyar Project with a series, of dams has also been completed. One of the special features of the dams in Tamil Nadu is the unique adoption of stone masonry instead of concrete masonry which is popular in other parts of the country. These are generally masonry-*cum*-earth dams. In the Masonry dam portion, hammer dressed stones and chisel dressed stones are used in front and rear for various thickness, while rough stones of various sizes are packed at random in the middle. Forty (40) cft. cement mortar is generally used for 100 cft. of stone masonry. The earth dam is of zoned sections of less pervious soils in the Central Section and more pervious soils in the outer zone, with horizontal filter running for the entire width of semi-pervious section in rear of the impervious zone.

1.3. In addition to proper designs, quality control and supervision in the execution of these irrigation dams, installation of instrument, is also essential. These instruments are installed in the different sections of the dams in the Masonry or concrete central sections as well as in the Earthern embankments, to study their structural behaviour during and after construction. The data obtained from such instruments installed in the foundations and in the appurtenant structures at different places are highly useful for comparison with the design assumptions and indicating potentially dangerous conditions, that are likley to develop during construction or in operation.

2. *Objective of the Study—*

2.1. Studies of such data besides yielding valuable results which can be used to promote better economy of construction and greater stability in their designs, can satisfactorily vouchsafe for the smooth operation of such dams in times to come. These results are also useful in correlating the results obtained by model studies on such hydraulic structures with those obtained from prototype structures. An attempt has been made to collect and analyse the readings of instruments embedded in one such masonry-*cum*-earth Dam in Tamil Nadu (via) Vaigai dam in Madurai district, since its construction to recent times. The results of a preliminary study on these results and the behaviour of the dam as brought out from those data, are presented in this paper.

3. *Scope of the Study.—*

3.1. The Vaigai Dam is built in Madurai District of Tamil Nadu at a distance of about 32·187 km. (20 miles) from Peranai Regulator near Andipatty Railway Station. A 192·44 M m^3 (6,800 M cft.) reservoir built across the Vaigai River stores the waters that are drawn from the Periyar lake for power development during non-Irrigation seasons and also a part of occasional surpluses from local rains in the Periyar and Vaigai catchments. Details of the Vaigai Dam are given in Statement 1 enclosed.

3.2. The instruments that have been embedded in the Vaigai dam during its construction are given below:—

MASONRY DAM

Joint meters	6 Nos.
Uplift meters	5 Nos.
"V" Notches in Gallery ..	4 Nos.

1. Former * Executive Engineer, Soil Mechanics and Research, Division, Chepauk, Madras-5 and Now S.E, P.W.D. (Retd.) 2. Research Officer, Soil Mechanics and Research Division, Chepauk, Madras-5. 3. Junior Research Assistant, Soil Mechanics and Research Division, Chepauk, Madras-5.

EARTH DAM

Piezometers .. .. 22 Nos. (tips)

Settlement apparatus with cross-arms. — One with 17 arms in the front side and one with 14 arms in the rear side.

" V " Notches .. .. 3 Nos.

3.3. Of these, the Upliftmeters are not functioning. Readings of all the other instruments have been collected, calculated and analysed. All the available readings since the initial stages of construction of the Project in 1956 to recent times up to 1965 have been used in this study.

4. *Procedure.—*

4.1. *Masonry Dam (i) Joint movements.*—Six joint meters are located across vertical construction joints in the masonry dam between blocks 9 and 10 and blocks 10 and 11 at elevations of 882·00. These are provided to take care of movements due to temperature and shrinkage in cement mortar masonry. The locations of these are given in Figure No. 1 enclosed. These joint-meters are of the " Carlson " type, electrically operated, in which two electrical resistance coils are sealed in suitable protective casings of metal and rubber tubing, which can be embedded in concrete or other material to reveal the internal deformations. Readings are taken with a testing kit or equivalent which consists of an A.C. bridge network and indicating balance meter. The description of the meter and its working are not given. Suffice it to say that two measurements are made (1) the cumulative resistance of the coils, being the tow-wire resistance and (2) resistance ratio, this being the observation made with 3 wires. The former is used for determining the temperature at the location where the meter is placed, while the later " the resistance ratio " depends on the strain produced, which is independent of the temperature and is used to measure the total elongation or contraction produced. The Jointmeter is embedded across a joint, half on each side so as to be stretched when the joint opens and compressed when the joint closes. Of these six joint meters, one (A2) has completely failed and only readings of the other five are available. The readings of all these five jointmeters from 1958, when they were first taken to 1964 have been obtained, joint movements and temperatures calculated and the variations plotted against time. A specimen table of calculations for the year 1962 for one Jointmeter A5 is enclosed as Table 1. Graphs of the temperatures induced and joint movements (displacements of the joints) obtained, for the year 1964 only are included in Figures 2, 3 and 5.

4.2. *Joint Movements and Temperatures.—*

4.2.1 " Constants " of the meters giving the two-wire resistance as 0° F, change in temperature per ohm change in resistance, calibration constant "inches per ·01% change in ratio " and the value of ratio for the jointmeter in the closed position are supplied with the meter. For a proper operation " the joint " will remain closed after installation until temperature drops down when the joint will open as cooling progresses and *vice versa* From a study of the curves, it is seen that there appears to be a little time lag between the temperature changes inside the material and the consequent streching or contraction induced by the material due to several reactions. The trend of " relative opening " of the joints for a temperature decrease and "relative closing " of the joints for a rise in temparature is generally found in all these curves. The maximum and minimum temperatures indicated by these meters is 155° F and 40° F and the maximum joint movements on either direction, negative (Joint closing) and positive (joint opening) indicated are (4·064 cm.) and (1·1176 cm.) respectively. For small fluctuations the joint movements are not pronounced. On several occasions the readings of both temperature and joint movements are erratic, probably due to reactions inside the masonry. The joints appear to be quite active either way even in 1964, about six years after the dam is commissioned. The maximum and minimum temperatures and the maximum joint movements indicated by the readings of these meters are given below :—

Year of observation.	Temperature. Max. °C	Min. °C	Joint movements in inches (max.) (+) relative opening.	(—) relative closing.
(1)	(2)	(3)	(4)	(5)
1958	52·2	14·0	·127 cm.	·3302 cm.
1959	41·0	21·1	·1524 cm.	·6604 cm.
1960	55·5	25·6	·4064 cm.	1·1938 cm.
1961	62·0	8·0	·4318 cm.	·1524 cm.
1962	68·0	33·3	·4572 cm.	0·8128 cm.
1963	64·5	4·5	·3556 cm.	4·572 cm.
1964	62·0	6·0	·381 cm.	4·064 cm.

4.2.2. The joint movements appear to be of a low order that they do not need any specific actions to be taken such as grouting, etc. The very high maximum temperatures of more than 48·9°C specifically indicates that they could not be due to external influence of the weather conditions. They probably indicate the existence of exothermic reactions.

4.3. (ii) *Seepage through masonry dam.—*

4.3.1. In masonry dams, there is always seepage of water through the masonry and under the foundations. In the Vaigai Dam and in most of the masonry dams in this State arrangements have been made to collect this water at the Drainage Gallery of the Dam and then letting it out into the river. In the Vaigai Dam four " V " notches have been provided in different blocks for collecting this entire water seeping through the masonry dam. It has been found that there is not much seepage through the foundations and that bulk of the seepage is from the masonry dam only.

4.3.2. The water that passes through the Dam dissolves some " Free lime " from the masonry which are released from the cement mortar. If the quantity of lime that is leached out is excessive, it will increase the permeability which may lead to weakening of the Dam. It is therefore essential that an estimate of the quantity of lime leached out be obtained to study the gravity of the situation.

5. *Lime Leaching by Seeping water—*

5.1. Portland cement used for mortar in the construction of the masonry portions of the dam consists of a mixture of an hydrous compounds. The predominant ones are silicates, aluminates and alumino ferrites of calcium besides small quantities of calcium oxide and magnesium oxide. During hydration and hydrolysis, the process in which cement sets and hardens, a certain quantity of " Free lime " is released. If a pozzolona is used with cement, a part of this lime combines with it in producing cementitious compounds. Some quantity of lime, however, is still available which is " free ". The water that seeps through the Dam dissolves this " Free lime " so released and forms calcium hydroxide. The seepage water just on emerging out of the masonry dam into the drainage shafts contain this lime obtained from cement as calcium hydroxide. On exposure to atmosphere this gets converted to calcium carbonate and gets deposited.

5·2. Pure water also has a slow action on the set cement compounds and decomposes them. Even alumina to some extent is attacked by water. Though the action on mortar is slow, continued seepage of water and the resulting depletion of lime may seriously endanger the structure. If the reservoir water contains sulphates in large concentrations, calcium sulphate and calcium sulpho-aluminate may be formed, which may cause severe damage to the structure. But such high sulphate concentrations are not generally found to occur.

5·3. *Sampling and tests :—*

5·3·1. For estimating the quantity of lime leached out, water samples are received and tested, from the dam. Every month, one water sample drawn from the reservoir and one sample of water collected from the gallery are obtained in glass bottles with water tight stoppers. The water level in the reservoir and the quantity of seepage are measured simultaneously, when the samples are drawn and sent for tests every month.

5·3·2. The water samples from the dam are tested by standard methods and the percentage of calcium salts present in each of them estimated and expressed as Cao per cent. A table showing the results of such analysis for the Vaigai Dam for the period from February 1960 to November 1963 is enclosed as Table 2.

6·0. *Analysis of results :—*

6·1. The reservoir water level, quantity of seepage water, litres/minute (Gallons/minute) and the quantity of lime eached for the period August 1957 to December 1964 have been analysed. The quantity of water seep in through the masonry dam and the quantity of lime leached thereby, generally show a positive proportional variation with the acting hydraulic head. The maximum values of seepage and quantity of lime leached are (240·938 litres/minute) and 3·5 tons/month. During the period October 1960 to October 1961 when the Reservoir level was steady at 915·00 (almost full) and the seepage per minute also was almost steady between 155–170 litres, the quantity of lime leached however was not constant, but decreased from as high as 3·048 tonnes/month to 0·7112 tonnes/month.

6·2. Calculations for obtaining the total quantity of cement used in constructing the masonry portion are given in the calculation sheet enclosed as Appendix I. The results show that the lime leached during the period February 1960 to November 1963 for 41 months is of the order of 1·1 per cent. The phenomenon of lime leaching proves to be an essential study in the computation of useful life of all masonry dams, since seepage cannot be completely stopped economically.

7. *Earth Dam :—*

7·1. The most important field observations for the behaviour of Earth Dams are those of consolidation and settlement of the embankment and foundation and measurements of internal pore pressures. The conclusions obtained from a study of such observations, provide a basis for the establishment of finite laws or principles that will permit predictions of soil mass behaviour under field conditions of saturation and of loading and the development of corresponding methods of control.

7·2. Instruments installed in the earth dam of Vaigai Project comprise of, piezometers for measurement of pore water pressures, settlement installation to determine the internal settlement and consolidation and " V " notches for measurement of the seepage through the earth dam. Details of those installations are given in Figure 6.

7·3. *Pore pressures in earth dam :—*

7·3·1. The closely packed soil particles that make up an earth dam embankment have inter-connected pore spaces between them which permit the flow of air and water through the materials. As the embankment consolidates and the reservoir fills up and empties, the air and water " The pore fluid " exerts pressures on the surfaces of the pore spaces. These pore pressures reduce the shearing strength of a soil by reducing the soil contact pressures and thereby reducing the frictional resistance. The distribution of pore pressures determine the flow of water through the embankment.

7·3·2. The importance of pore pressure measurements therefore needs no emphasis. The Engineers of " The Bureau of Reclamation " are of the opinion that " In several of the World's highest earthfill dams, pore pressure measurements have proved that the most critical condition for stability of an earth dam occurs during the construction period. In view of the experience gained by the Bureau of reclamation since 1936 from the data of pore pressures, it has now been possible to incorporate such data into the design of new structures with much more certainty as to the behaviour of the dam than was possible when pore pressures were not considered ".

7·4. *Pore pressure installation :*

7·4·1. Twenty-two numbers of piezometer tips have been installed in the Vaigai Dam at L.S. 3050. The locations of these piezometer tips are shown in Figure 6. The piezometer tip consists of two tubes filled with water, with one end open at some location in the earth dam or foundation and the other end connected to a gauge in a terminal well at the down stream toe of the embankment. The pore pressure acts through a porous disc on to the liquid in the tubings and is indicated on the pressure gauge in the terminal well. Two types of tips are available one for the foundations and the other for use in the embankments. Details of these and the method of installation are given in the Earth Manual (1). These tips are installed during the construction of the dam and thus record the pressures developed during construction as well as during operation. Pore pressure measured on 9th January 1959 are shown in the figure 9.

7·4·2. *Pore pressure observations :—*

The readings obtained from these observations which give the pore pressures at the tip " in feet of water " enable us to determine the pore pressures in the embankment, the extent of saturation, the location of the phreatic line (viz.) the line of zero pore pressure and the flow pattern. These data are useful for studying the percolation through the embankment and in the stability analysis of the earth dam. The pore pressure data are studied by first drawing " equal pressure lines ". These lines are drawn from a plot of the pore pressure values at the locations of the Piezometer tips in the dam.

8·0. *Installations for settlement and consolidation :—*

8·1. The question of settlement and consolidation in earth dams require consideration from the stand point of appearance, maintenance of the desired free board, volume from borrowpit, excavation, and cracking of structures. The installation for this consists of external and internal systems of settlement points and observations. The internal indicating system is used in Vaigai dam for observing the settlement of the foundation which consists of a series of alternating 3·81 cm. and 5·09 cm. pipes with the 3·81 cm. pipes anchored to the embankment by a ·9144 cm. channel iron cross arm. Each anchored pipe section move with the embankment and independently of the rest of the installation. The elevations of the various anchored sections are determined by lowering a special device called a " Torpedo " which engages into the pipes by a steel chain. The distances from a scale to the anchored pipe section is measured and the elevation of the pipe obtained. The elevation of the scale is obtained from a point outside the dam area. Pawls on the engaging device successively engage the ends of the anchored pipe until on reaching the bottom of the installation, the pawls are latched closed and the device can be withdrawn. Details of this instrument " The telescoping pipe system " and the method of installation and observation can be found in the Earth Manual (1).

8·2. Two sets of such installations have been installed in the Vaigai Dam at L.S. 3100. One set consisting of 17 cross arms has been installed at 9·906 m. from the centre "on the front side" of the dam while a second set consisting of 14 cross arms has been installed at a distance of 6·096 m ' on the rear side ".

Analysis of results :—

8·3·1. Data from these installations help to have a complete picture of the behaviour of the earth dam, since (1) the amount of consolidation compared to the pore pressures developed, (2) the settlement and the consequent densities obtained in the embankment, (3) the consolidations of the foundation as well as of the earth dam and (4) the lateral movements, if any, can be studied using the results obtained.

8·3·2. For an understanding of the conditions inside the Earth dam, let us examine an increment of the embankment in the centre of the impervious zone during construction. This increment is composed of soil particles water and air. As load is added increment consolidation occurs. The soil particles and the water are, for all practical purposes, incompressible. So the consolidation can take place only by extrusion of the pore fluid, air and water, or in compression of the air. At the centre of a large impervious section, where extrusion of the fluid would require flow through large heights of tightly compacted impervious material, the extrusion of the pore fluid is a very slow process. Thus consolidation results mainly in the volume change of air in the pores. According to Boyle's law everyone knows that pressure varied inversely as the volume. Thus if the initial volume is small to begin with, even a small consolidation will result in a high pore pressure. The period at the completion of construction is a critical one, as it is the point of maximum load and minimum time for dissipation of the pore pressures.

8.3.3. It can be observed from Figure 7 that such conditions existed in the Vaigai Dam during its construction. The high pore pressure conditions inside the central hearting section during the construction of the embankment can be seen from the pore pressures diagram. It was seen that the observed pore pressures in the beginning are similar to draw down conditions and indicates the necessity for a zoned embankment having a pervious upstream section to give support to the slope.

8.3.4. The settlement and consolidation make an interesting study when the embankment construction and the reservoir filling in and emptying out are taken into consideration. The foundation settlement is only small about 30·48 cm. whereas the foundation consolidation is still small only about 16·1544 cm. The rear portion of the dam has settled 10·16 cm. more than the front portion About half the settlement has occurred after the construction is over. Only about a fifth of the foundation consolidation of cross-arm 2-(F), 1-(R) and 2-(R) indicate positive and negative consolidations due to initial filling in and depletion of the reservoir. The embankment has taken about $1\frac{1}{2}$ years to settle down due to the fluctuations in the reservoir water level. The " consolidation height of fill curves " of both the 1st cross-arms lowest ever indicate a primary consolidation followed by a subsequent secondary consolidation.

8.3.5. The total settlement a structure can undergo without trouble is large provided it is uniform. However with large amounts of settlement several forms of troubl develop. This results in the lowering of the crest and hence loss of height and free-board. The total settlement of this dam appears to be quite small.

9.0. *Seepage—*

9.1. One of the considerations in the design of an earth dam is the minimising of seepage or percolation through the embankment. Even the tightest compacted earth fill is not entirely impervious, since the pore spaces in the material permit the passage of water. The problem of percolation does not loom quite so large now in view of the better understanding of soil mechanics and experiences gained from the fact that even dams with leakage of about 0·849 m3 (about 49,486 litre/min.) are operating satisfactorily. However, it is useful to have an idea of the quantity of water and hence reservoir storage lost by way of percolation through the earth dams.

9.2. The quantity percolating through the earth dam is neglible about (1,480 litres/minute) when the reservoir is almost full.

10.0. *Conclusion—*

10.1. A preliminary study has been made on the behaviour of a masonry-*cum*-earth dam in the Tamil Nadu from the available readings of Jointmeters, Pore pressure tips, settlement cross-arm installations and readings of quantity of water seeping through the moasnry dam and percolating through the earth dam on either side. The results of this study will be useful for comparison with the computations and assumptions made in the designs for this dam and in similar studies for other masonry dams. These results will be useful for checking up the working of the different instruments and " in-situ " conditions and to decide upon the type and number of such instruments to be installed in such dams in future. Since good behaviour is a " must " for good and proper design, such studies on available data of irrigation dams in the country need a high priority in our Research programmes.

REFERENCES.

1. *Earth Manual*—U.S.B.R. Department of Interior—A reclamation Manual Specialist—Supplement—Denver, Colorado.

2. Creager, ustin and Hinds—Engineering for Dams

3. Treatise on Dams—U.S.B.R.—Chapter VIII—Earth Dams.

4. Terzaghi and Peck—Soil Mechanics in Engineering Practice.

5. Sowers—Earth and Rock fill Dam Engineering.

6. Fourth Congress on Large Dams—Proceedings.

7. Depletion of Lime in Masonry Dams—Paper presented by the Concrete Soil Research Laboratory, Madras, at the 34th Annual Session of the Central Board of Irrigation and Power—June 1954.

8. Study of Joint movements in a Masonry Dam—Paper presented by the Concrete and Soil Research Laboratory, Madras, at the 35th Annual Session of the Central Board of Irrigation and Power—June 1965.

STATEMENT No. 1.

VAIGAI RESERVOIR PROJECT.

Location	..	About 32·187 Km. above Peranai Regulator in Madurai district. To store the surplus waters diverted from the Periyar Lake and also the surplus of Vaigai River.
Dam	..	Height 106 ft. (32·309 m). Length : 315·468 m (Masonry dam). 542·544 m (earth dam) on the left flank. 5504·688 m (earth dam) on the right flank.
Quantity	..	Concrete and masonry 5 M.cft. (141500 m³). Earth—735800 m³.
Reservoir	..	Storage capacity 6,878 M.cft (224647400 m³).
Canals	..	$17\frac{1}{2}$ miles long (23·164 km.)
Benefits	..	Extensions of Irrigation to an extent of 20,000 acres in Ramanathapuram and Madurai district. Assistance to Vaigai ayacut by storing Vaigai surplus, if any.
Cost	..	Rs. 3·30 crores.
Progress	..	Started in April 1954. Opened for irrigation in July 1958.

TABLE

VAIGAI DAM.

JOINT METER DATA.

Joint Meter No. A-5.

Project : Vaigai Dam.

Calibration : Constants of the Jointmeter.

(i) Meter resistance with cables .. .. .. 50·35 chms.

(ii) Change in temperature per ohm. / Change in resistance ... } .. .. 10·87°F. (—) 11. 74 %

(iii) Calibration constant .. .. 0·0011303 cm. per 0·01 per cent ratio change.

(iv) Ratio closed .. .. 96 per cent.

Date.	*Meter resistance (chms.)*	*Temperature °C*	*Resistance ratio per cent.*	*Change in ratio per cent.*	*Indicated movement (cm.)*
(1)	(2)	(3)	(4)	(5)	(6)
3rd January 1962	62·08	53·00	98·00	2·00	0·2260
10th January 1962	62·47	55·50	98·10	2·10	0·2375
18th January 1962	62·36	54·75	98·50	2·50	0·2827
26th January 1962	61·96	52·30	98·96	2·96	0·3345
3rd February 1962	62·40	55·00	98·19	2·16	0·2476
10th February 1962	62·20	53·56	97·40	1·40	0·1582
26th February 1962	61·83	51·70	96·44	0·44	0·0498
3rd March 1962	61·50	49·50	96·80	0·80	0·0904
10th March 1962	61·10	47·20	96·60	0·60	0·0678
18th March 1962	62·19	53·56	96·20	0·20	0·0226
26th March 1962	63·18	60·00	97·25	1·25	0·1412
3rd April 1962	62·97	58·75	96·60	0·60	0·1019
10th April 1962	62·80	57·20	96·60	0·60	0·0678
18th April 1962	61·28	48·40	96·21	0·21	0·0236
26th April 1962	63·16	60·00	96·46	0·46	0·0521
3rd May 1962	63·58	62·20	96·47	0·47	0·0521
10th May 1962	63·00	59·00	96·20	0·20	0·0226
18th May 1962	62·80	57·20	95·90	0·10	0·0114
26th May 1962	63·27	60·50	96·86	0·86	0·0973
3rd June 1962	63·00	59·00	97·20	1·20	0·1356

Date.	*Meter resistance (chms).*	*Temparature 'C'*	*Resistance ratio per cent.*	*Change in ratio per cent.*	*Indicated movement (cm.)*
(1)	(2)	(3)	(4)	(5)	(6)
10th June 1962	62·20	53·55	98·20	2·20	0·2486
18th June 1962	62·59	56·20	97·90	1·90	0·2154
26th June 1962	62·80	57·20	98·26	2·26	0·2555
3rd July 1962	62·28	54·00	98·70	2·70	0·3054
10th July 1962	61·60	50·00	98·40	2·40	0·2713
18th July 1962	62·00	52·20	98·20	2·20	0·2486
26th July 1962	62·60	56·50	98·60	2·60	0·2939
3rd August 1962	62·76	56·00	98·60	2·60	0·2939
10th August 1962	62·50	55·50	99·24	2·24	0·2532
18th August 1962	62·00	52·20	98·00	2·00	0·2261
26th August 1962	61·73	50·50	97·65	1·75	0·1979
3rd September 1962	61·70	50·50	97·27	1·27	0·1412
10th September 1962	62·15	53·50	97·22	1·22	0·1379
18th September 1962	62·28	54·00	97·11	1·11	0·1267
26th September 1962	62·70	50·50	96·84	0·84	0·0950
3rd October 1962	62·52	55·50	96·31	0·31	0·0352
10th October 1962	62·65	56·50	96·50	0·50	0·0566
18th October 1962	62·70	56·00	97·20	1·20	0·1356
26th October 1962	62·80	56·50	97·40	1·40	0·1582
3rd November 1962	62·80	55·00	98·26	2·26	0·2555
10th November 1962	62·80	56·50	98·40	2·40	0·2713
18th November 1962	62·90	58·50	98·90	2·90	0·3409
26th November 1962	63·27	60·00	100·15	4·15	0·4691
3rd December 1962	62·70	55·50	96·70	0·70	0·0192
10th December 1962	62·62	55·00	98·40	2·40	0·2713
18th December 1962	62·08	54·00	98·00	2·00	0·2261
26th December 1962	63·10	59·50	99·60	3·60	0·4069

TABLE 2.

VAIGAI RESERVOIR PROJECT.

SEEPAGE THROUGH MASONRY QUANTITY LIME LEACHED.

Serial number and month and year. (1)	Reservoir level. (2)	Calcium carbonate content. Gallery water. (3)	Reservoir water. (4)	Difference (per cent). (5)	Lime leached as CaCo 3 (6)	Rate of See page Ltre Min. (7)	Quantity of see page (litres) for a month. (8)	Lime leached calcium Oxide (ca) (tonnes). (9)
1 February 1960	364·56	0·077	0·004	0·073	0·041	56·3	24,36,000	0·9809
2 March 1960	268·53	0·032	0·004	0·028	0·016	98·5	42,64,000	0·6687
3 April 1960	275·23	0·009	C·006	0·003	0·016	173·4	75,04,000	0·1179
4 May 1960	276·84	0·066	0·005	0·061	0·034	239·3	03,50,000	3·4570
5 July 1960	277·00	0·067	0·003	0·064	0·036	167·5	72,49,000	2·5680
6 August 1960	276·22	0·068	0·003	0·065	0·036	163·5	70,89,000	2,5050
7 September 1960	272·12	0·029	0·005	0·024	0·013	114·0	49,35,000	0·6296
8 October 1960	268·50	0·070	0·003	0·067	0·037	67·2	29,08,000	1·0560
9 November 1960	278·90	0·059	0·005	0·054	0·030	252·9	09,40,000	3·2220
10 December 1960	278·37	0·046	0·005	0·041	0·023	235·7	1,02,00,000	2·3030
11 January 1961	278·25	0·052	0·006	0·046	0·026	169·3	73,21,000	1·8690
12 February 1961	275·25	0·080	0·007	0·073	0·041	122·6	53,04,000	2·1340
13 March 1961	276·25	0·053	0·006	0·047	0·026	130·0	56,22,000	1·4340
14 April 1961	278·40	0·029	0·005	0·024	0·013	147·5	63,84,000	0·8149
15 May 1961	278·50	0·037	0·004	0·033	0·018	155·4	67,26,000	1·1890
16 June 1961	278·40	0·033	0·012	0·021	0·012	150·4	65,07,000	0·7668
17 July 1961	278·50	0·026	0·003	0·023	0·013	155·4	67,26,000	0·8582
18 August 1961	276·22	0·035	0·004	0·031	0·017	130·0	56,22,000	0·9378
19 September 1961	272·12	0·036	0·004	0·032	0·018	56·4	24,56,000	0·4340
20 October 1961	268·50	0·082	0·005	0·077	0·043	40·5	20,47,000	0·8294
21 December 1961	278·40	0·032	0·006	0·026	0·014	166·8	72,19,000	0·0019
22 January 1962	274·50	0·061	0·005	0·056	0·031	77·6	33,59,000	1·023
23 February 1962	270·50	0·077	0·006	0·071	0·039	59·0	25,54,000	0·9779
24 March 1962	272·20	0·023	0·005	0·018	0·010	69·0	29,86,000	0·2932
25 May 1962	277·12	0·027	0·006	0·021	0·012	122·6	53,08,000	0·6253
26 April 1962	275·00	0·027	0·008	0·019	0·011	9·0	38,51,000	0·4159
27 June 1962	278·00	0·030	0·004	0·026	0·014	122·6	53,08,000	0·7295
28 July 1962	270·30	0·019	0·005	0·014	0·008	122·6	53,08,000	0·4169
29 August 1962	272·50	0·019	0·004	0·015	0·008	81·3	3,51,900	0·2763
30 September 1962	273·00	0·025	0·004	0·021	0·012	81·3	35,19,000	0·4104
31 October 1962	278·50	0·042	0·034.	0·012	0·007	147·5	63,84,000	0·4388
32 November 1962	278·30	0·055	0·005	0·051	0·028	134·8	58,34,000	1·6040
33 December 1962	277·30	0·041	0·004	0·037	0·021	122·6	53,08,000	1·0940
34 January 1963	277·60	0·004	0·000	0·004	·00	77·6	33,59,000	0·0659
35 February 1963	274·00	0·042	0·006	0·036	0·020	518·0	22,40,000	0·4397
36 May 1963	277·20	0·071	0·012	0·059	0·0333	95·8	41,46,000	1·3430
37 June 1963	276·30	0·053	0·010	0·043	0·024	95·8	41,46,000	0·9768
38 July 1963	275·00	0·040	0·009	0·031	0·017	617·0	26,72,000	0·4461
39 August 1963	273·50	0·029	0·005	0·024	0·013	45·5	19,78,000	0·2524
40 September 1963	267·3	0·065	0·005	0·060	0·033	31·4	13,60,000	0·4532
41 November 1963	271·2	0·029	0·003	0·026	0·014	57·6	24,94,000	0·3427

TABLE 3.

SETTLEMENT APPARATUS READING FOR THE YEAR 1959.

Front Side

Settlement of cross arm in Cm.

Date. (1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
13th January 1959	1·524	17·98	14·326	20·726	18·288	20·117	25·603	29·567
13th February 1959	2·1336	18·553	20·117	21·641	18·288	20·422	26·832	31·09
13th March 1959	2·7432	21·641	20·726	22·555	19·202	21·641	27·737	32·309
13th April 1959	3·048	21·945	21·031	22.555	19·507	21·945	27·737	32·00
13th May 1959	3·353	22·25	21·336	22·860	19·507	22·25	27·737	32·009
13th June 1959	3·961	22·25	21.336	23·165	20·117	22·25	27·737	32·910
13th July 1959	8·534	24·993	26·822	28·346	24·993	29·937	33·528	37·490
13th August 1959	12·802	29·261	30·785	32·614	29·261	32·309	37·795	42·060
12th September 1959	12·802	29·261	31·09	32·614	29·261	32·309	38·10	42·300
13th October 1959	12·802	29·261	31·09	32·614	29·567	32·309	38·10	42·300
13th November 1959	13·106	29·567	31·39	32·918	29·87	32·614	38·405	42·3000
16th December 1959	13·106	29·567	31·39	32·918	29·87	32·614	38·71	42·3000

TABLE 3-A.

SETTLEMENT APPARATUS READING FOR THE YEAR 1959.

Rear Side.

Settlement across arm in Cm.

Date. (1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
13th January 1959	9·144	15·545	20·117	37·432	29·567	20·785	32·001	30·48
13th February 1959	9·144	15·545	20·117	27·432	30·48	33·528	34·052	3·528
13th March 1959	9·449	17·98	20·117	30·175	32·918	34·138	35·966	34·442
13th April 1959	11·887	18·288	22·25	27·737	33·233	34·052	36·576	35·350
13th May 1959	11·887	18·288	22·555	27·737	33·223	36·576	37·795	36·271
13th June 1959	13·411	18·288	22·555	27·737	33·223	38·10	34·405	37·186

TABLE 3—*cont*

SETTLEMENT APPARATUS READING FOR THE YEAR 1959—*cont.*

Front Side.

Settlement of cross arm in Cm.

Date.	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
13th January 1959	35·966	40·843	39·923	40·843	43·586	42·672	41·453	40·538	38·120
13th February 1959	37·795	45·315	42·062	43·586	43·586	44·806	43·282	42·672	40·538
13th March 1959	39·014	46·330	42·977	43·897	44·806	46·330	44·501	43·827	41·578
13th April 1959	39·319	46·939	43·586	44·196	45·110	46·330	44·806	44·195	42·364
13th May 1959	39·624	50·60	44·196	44·806	45·720	46·939	45·315	46·806	42·977
13th June 1959	39·929	48·158	44·196	44·806	45·720	47·23	45·720	45·110	43·282
13th July 1959	44·806	49·987	49·073	49·987	51·206	52·121	50·60	50·292	48·463
13th August 1959	49·073	54·25	53·035	53·55	55·474	46·693	55·474	55·169	53·035
12th September 1959	49·378	54·25	53·645	54·25	55·778	56·938	55·778	55·778	53·645
13th October 1959	49·378	54·25	53·645	54·25	55·778	56·938	56·778	55·778	53·645
13th November 1959	49·682	54·589	53·95	54·599	56·086	57·302	56·083	56·083	54·25
16th December 1959	49·682	61·874	53·95	54·599	36·388	57·302	56·083	56·083	54·559

TABLE 3-A.

SETTLEMENT APPARATUS READING FOR THE YEAR 1959.

Front Side.

Settlement across arm in Cm.

Date. (1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
13th July 1959	15·24	21·945	25·603	33·833	36·881	42·062	45·315	44·196
13th August 1959	15·85	22·25	26·21	34·344	37·79	43·28	46·63	46·03
12th September 1959	15·85	22·25	26·21	34·44	37·79	43·28	46·94	46·03
13th October 1959	15·85	22·25	26·21	34·44	37·79	43·28	46·94	46·03
13th November 1959	15·85	22·25	26·52	34·44	37·79	43·28	46·94	46·03
16th December 1959	16·46	22·25	26·52	34·44	37·79	43·28	46·94	46·03

TABLE 3-A—*cont.*

SETTLEMENT APPARATUS READING FOR THE YEAR 1959—*cont.*

Front Side.

Settlement across arm in Cm.

Date.	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
13th January 1959	30·175	29·261	27·737	27·737	27·127	25·602	..	..	..
13th February 1959	31·699	32·614	31·19	30·785	30·48	28·956	..	..	..
13th March 1959	33·833	32·223	32·001	31·699	31·09	29·87	..	..	..
13th April 1959	34·747	34·442	32·918	32·918	32·309	31·09	..	..	..
13th May 1959	35·966	35·357	34·138	33·833	33·223	32·309	..	..	..
13th June 1959	36·576	36·271	34·747	34·442	33·833	32·614	..	..	..
13th July 1959	42·977	43·282	41·578	42·062	41·453	40·234	..	..	..
13th August 1959	45·11	44·81	43·59	43·90	43·28	42·06	..	..	..
12th September 1959	45·32	45·11	43·90	44·50	43·90	42·67	..	..	..
13th October 1959	45·32	45·11	43·90	44·50	44·50	42·67	..	..	..
13th November 1959	45·32	45·11	44·12	44·50	44·20	42·94	..	..	..
16th December 1959	45·72	45·32	44·50	44·61	44·50	43·28	..	..	..

TABLE 4.

VAIGAI DAM.

SETTLEMENT DATA CONSOLIDATION OF CROSS ARMS IN CMS (FRONT SIDE).

Date and time of reading.

Consolidation between arm Nos.	1956				1957						
	7/5	15/9	5/11	19/11	7/3	26/4	22/7	12/8	2/9	7/12	31/12
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
1 and 2	..	0	6·710	9·5	10·4	10·4	10·4	10·67	10·67	11·28	12·19
2 and 3	..	0·0	0·0	3·35	3·96	4·88	4·88	5·75	6·40	6·71	7·62
3 and 4	..	..	..	0·0	3·05	3·05	3·35	3·96	..	4·57	4·57
4 and 5	..	..	..	..	0·0	3·05	0·06	0·09	0·12	0·18	0·18
5 and 6	..	..	..	..	..	0·0	3·66	0·03	0·03	0·03	0·03
6 and 7	..	..	..	..	..	..	0·0	0·03	0·06	0·06	0.06
7 and 8	..	..	..	..	..	..	..	0·0	0·00	0·00	0·00
8 and 9	..	..	..	..	..	..	..	..	0·0	0·03	0·03
9 and 10	..	..	..	..	..	..	..	..	..	0·00	0·0
10 and 11	..	..	..	..	..	..	..	..	..	..	..
11 and 12	..	..	..	..	..	..	..	..	..	..	..
12 and 13	..	..	..	..	..	..	..	..	..	..	..
13 and 14	..	..	..	..	..	..	..	..	..	..	..
14 and 15	..	..	..	..	..	..	..	..	..	..	..
15 and 16	..	..	..	..	..	..	..	..	..	..	..
16 and 17	..	..	..	..	..	..	..	..	..	..	..

TABLE 4—*cont.*

VIAGAI DAM—*cont.*

SETTLEMENT DATA CONSOLIDATION OF CROSS ARMS IN CMS. (FRONT SIDE)—*cont.*

Date and time of reading—cont.

Consolidation between arm Nos.	1958							
	13/1	13/3	3/7	10/7	18/7	18/7	13/11	13/12
(1)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
1 and 2	12·80	12·80	12·80	12·80	12·80	13·91	14·33	16·46
2 and 3	7·62	7·92	7·92	7·92	8·53	8·53	3·66	8·84
3 and 4	5·49	5·49	6·10	0·18	6·40	6·40	6·70	9·75
4 and 5	0·18	0·18	0·18	0·06	0·18	0·23	..	2·74
5 and 6	0·03	0·06	0·06	0·12	0·09	0·09	..	3·35
6 and 7	0·06	0·06	0·12	0·18	0·12	0·12	5·79	6·40
7 and 8	0·03	0·03	0·03	0·09	0·03	0·06	3·35	6·40
8 and 9	0·03	0·06	0·09	0·12	0·12	0·12	0·21	7·92
9 and 10	0·06	0·06	0·09	0·03	0·12	0·15	0·21	7·01
10 and 11	0·03	0·03	0·03	0·06	0·03	0·03	0·09	0·12
11 and 12	0·0	0·03	0·03	0·03	0·06	0·12	0·12	0·30
12 and 13	..	0·0	0·03	0·03	0·03	0·03	0·06	4·57
13 and 14	..	..	0·00	0·00	0·00	0·03	0·06	0·09
14 and 15	..	..	..	0.0	0·03	0·03	0·00	0·00
15 and 16	..	..	..	..	0·0	0·03	0·03	0·06
16 and 17	..	..	..	..	..	0·0	0·03	0·03
..	..	..	..	..	..	..	0·0	..

TABLE 4—*cont.*

VAIGAI DAM.

SETTLEMENT DATA CONSOLIDATION OF CROSS ARMS IN CMS. (FRONT SIDE).

Date and time of reading.

Consolidation between arm Nos.	1959									
	13/1	13/2	13/3	13/4	14/5	13/6	13/7	13/8	12/9	13/10
(1)	(21)	(22)	(23)	(24)	(25)	(26)	(27)	(28)	(29)	(30)
1 and 2	16·46	16·46	18·99	18·86	18·86	15·24	16·46	16·46	16·46	16·46
2 and 3	..	8·84	6·40	6·40	6·4	6·4	9·14	8·84	9·14	9·14
3 and 4	11·89	7·01	7·32	7·01	7·01	8·23	7·01	7·32	7·01	7·01
4 and 5	3·66	2·74	2·74	3·05	2·74	3·05	2·74	2·74	3·05	3·05
5 and 6	3·05	3·35	3·66	3·66	3·96	3·35	3·76	4·27	3·96	3·96
6 and 7	6·71	7·01	7·32	6·71	6·40	6·40	6·71	6·40	6·71	6·71
7 and 8	6·10	7·01	6·71	7·01	7·32	7·62	6·40	6·71	11·58	11·58
8 and 9	7·32	8·23	8·23	8·53	8·53	8·53	8·84	8·53	8·53	8·53
9 and 10	6·71	10·36	9·75	9·75	10·05	10·36	7·32	7·32	7·01	7·01
10 and 11	0·12	0·12	0·12	0·12	0·12	0·18	0·12	0·09	0·15	0·15
11 and 12	0·30	0·30	0·27	0·27	0·27	0·27	0·30	0·30	0·27	0·27
12 and 13	0·03	0·27	0·27	0·27	0·27	0·27	0·30	0·33	0·33	0·33
13 and 14	0·39	0·33	0·30	0·27	0·30	0·33	0·27	0·30	0·30	0·30
14 and 15	0·00	0·06	0·03	0·03	0·03	0·03	0·03	..	0·00	0·00
15 and 16	0·03	0·09	0·09	0·09	0·09	0·09	0·12	0·12	0·15	0·15
16 and 17	0·00	0·00	0·00	0·03	0·03	0·03	0·03	..	0.00	..
17 ..	..	..	..	..	..	..	..	..	..	..

TABLE 4(a)—*cont.*

VAIGAI DAM.

SETTLEMENT DATA CONSOLIDATION OF CROSS ARMS IN CMS (REAR SIDE).

Date and time of reading.

Consolidation between arm Nos.	1956				1957						
	7/9	15/9	5/11	19/11	7/3	26/4	22/7	12/8	2/9	7/12	31/12
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
1 and 2	..	..	..	..	0	0	0	0·61	1·2	1·2	2·13
2 and 3	..	..	..	..	..	0	0	0·30	0·30	0·61	0·91
3 and 4	..	..	..	..	..	..	0	0·00	0·30	0·30	0·30
4 and 5	..	..	..	.	..	..	..	..	0·30	0·30	0·61
5 and 6	..	..	..	..	..	...	..	..	..	0·30	0·30
6 and 7	..	..	..	..	..	..	..	..	..	..	0·61
7 and 8	..	..	..	..	..	..	..	..	..	..	..
8 and 9	..	..	..	..	..	..	..	..	..	..	..
9 and 10	..	..	..	..	..	..	..	..	..	..	..
10 and 11	..	..	.	.	..	..	..	..	..	..	..
11 and 12	..	..	..	..	..	..	..	..	..	..	..
12 and 13	..	..	..	..	..	..	..	..	..	..	..
13 and 14	..	..	..	..	..	..	..	..	..	..	..

TABLE 4 (a)—*cont.*

VAIGAI DAM.

SETTLEMENT DATA CONSOLIDATION OF CROSS ARMS IN CMS (REAR SIDE).

Date and time of reading.

Consolidation between arm Nos.	1958							
	13/1	13/3	5/7	10/7	18/7	28/7	13/11	13/12
(1)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
1 and 2	2·74	2·05	3·05	3·05	3·35	3·65	5·79	7·61
2 and 3	0·91	0·91	1·2	1·2	1·52	1·52	1·52	4·57
3 and 4	0·61	0·91	1·2	1·2	1·2	1·52	1·82	3·35
4 and 5	0·61	0·61	0·91	0·91	0·91	1·2	1·2	4·88
5 and 6	0·30	0·61	0·61	0·91	1·2	1·2	1·83	2·13
6 and 7	0·61	0·61	1·2	1·2	1·2	1·2	1·2	4·65
7 and 8	0·61	0·61	0·61	0·91	0·91	1·20	1·20	1·50
8 and 9	..	0·30	0·30	0·30	0·30	0·30	0·0	0·91
9 and 10	..	..	0·0	0·60	0·60	0·60	1·50	0·60
10 and 11	..	..	..	0·00	..	0·00	0·30	0·30
11 and 12	..	..	..	..	0·30	0·60	0·60	0·91
12 and 13	..	..	..	..	..	0·90	0·60	9·91
13 and 14	..	..	..	..	..	..	0·30	0·30

TABLE 4 (a)—cont

VAIGAI DAM

SETTLEMENT DATA CONSOLIDATION OF CROSS ARMS IN CMS (REAR SIDE)—cont.

Date and time of reading.

Consolidation between arm Nos.	1959									
	13/1	12/2	13/3	13/4	14/5	13/6	13/7	13/8	12/9	13/10
(1)	(21)	(22)	(23)	(24)	(25)	(26)	(27)	(28)	(29)	(30)
1 and 2	7·01	7·01	9·14	7·01	10·06	5·69	7·31	7·01	7·01	10·15
2 and 3	3·35	2·13	4·35	3·96	4·26	4·26	3·65	3·96	3·96	3·96
3 and 4	7·31	7·31	7·31	5·69	5·39	5·39	8·20	8·20	8·20	8·20
4 and 5	3·05	3·95	6·40	6·40	6·40	6·40	7·95	4·26	4·26	4·26
5 and 6	2·74	1·2	2·44	3·05	3·35	0·61	6·7	7·01	11·89	11·89
6 and 7	3·05	3·65	3·95	3·65	3·35	2·33	8·20	8·20	8·50	8·50
7 and 8	1·20	1·20	1·20	1·50	1·20	1·50	1·50	2·01	1·81	1·81
8 and 9	1·82	1·51	0·03	1·50	1·51	1·50	0·91	1·20	1·50	1·50
9 and 10	0·91	0·91	2·33	1·20	0·91	1·20	1·81	1·20	1·20	1·20
10 and 11	0·30	0·60	0·30	0·30	0·60	0·30	0·30	0·60	0·60	0·60
11 and 12	0·60	0·60	0·60	0·30	0·60	0·60	1·20	1·20	1·20	1·20
12 and 13	0·91	0·91	1·20	0·91	0·91	0·91	0·91	0·91	0·91	0·91
13 and 14	0·30	0·60	0·30	0·60	0·91	0·60	0·60	0·60	0·60	0·60

TABLE 5.

VAIGAI DAM PIEZOMETER READING—cont.

Date.	*Reservoir Level.*	*Piezometer number,*						
		1	2	3	4	5	6	
		Elevation of Piezometer from Ground Level.						
		39	39	39	39	39	17	17
		Pore pressure at Tip (Cms. of Water).						
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
10th January 1965	+ 887·2	2,170·18	1,959·86	1,822·70	1,679·45	1,539·24	1,045·46	868·68
25th January 1965	+ 880·8	1,926·34	1,822·70	1,716·02	1,509·24	1,435·61	1,078·99	1,008·89
10th February 1965	+ 872·5	1,679·45	1,539·24	1,539·24	1,505·71	1,505·71	1,161·29	975·36
25th February 1965	+ 867·5	1,575·82	1,505·71	1,505·71	1,435·61	1,365·50	938·78	905·26
25th March 1965	+ 864·4	1,539·24	1,505·71	1,469·14	1,435·61	1,399·03	905·26	868·68
10th April 1965	+ 868·6	1,609·34	1,539·24	1,505·71	1,469·14	1,435·61	938·78	905·26
26th April 1965	+ 871·3	1·679·45	1,539·24	1,539·24	1,505·71	1,505·71	1,008·89	975·36
10th May 1965	+ 879·8	1,926·34	1,822·70	1,716·02	1,539·24	1,435·61	1,078·99	1,008·89
25th May 1965	+ 884·2	2,100·07	1,926·34	1,822·70	1,716·02	1,539·24	1,078·99	1,008·89
10th June 1965	+ 887·5	2,017·18	1,969·86	1,822·70	1,679·45	1,539·24	1,078·99	1,008·89
25th June 1965	+ 882·2	1,959·86	1,822·70	1,679·45	1,609·34	1,539·24	1,008·89	938·78
10th July 1965	..	1,679·45	1,609·34	1,539·24	1,505·71	1,469·14	975·36	938·78
25th July 1965	+ 864·2	1,539·24	1,505·71	1,469·14	1,435·61	1,399·03	905·26	868·68
10th August 1965	+ 882·8	1,539·24	1,505·71	1,469·14	1,435·61	1,399·03	805·26	868·68
25th August 1965	+ 865·0	1,539·24	1,505·71	1,469·14	1,435·61	1,399·03	905·26	868·68
10th September 1965	+ 856·6	1,469·14	1,435·61	1,383·19	1,350·26	1,295·40	868·68	798·58
25th September 1965	+ 848·7	1,328·93	1,295·40	1,280·16	1,258·82	1,258·82	835·15	798·58
10th October 1965	+ 878·1	1,926·34	1,822·70	1,716·02	1,539·24	1,469·14	1,078·99	1,161·29
26th October 1965	+ 881·3	2,100·07	1,926·34	1,822·70	1,716·02	1,539·24	1,078·99	1,008·89
10th November 1965	+ 871·2	1,679·45	1,539·24	1,539·24	1,505·71	1,505·71	1,008·89	975·36
25th November 1965	+ 868·9	1,609·34	1,539·24	1,505·71	1,469·14	1,435·61	938·78	905·26

TABLE 5—*cont.*

VAIGAI DAM PIEZOMETER READING—*cont.*

Date.	Reservoir Level.	*Piezometer numbers.* 8	9	10	11	12	13	14
		Elevation of Piezometer from Ground Level. 17	17	17	2	2	2	2
		Pore pressure at tip (Cms. of water).						
(1)	(2)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
10th January 1965	+ 887·2	798·58	798·58	765·05	481·58	411·48	307·85	251·27
15th January 1965	+ 880·8	938·78	798·58	765·05	481·58	448·08	341·38	307·85
10th February 1965	+ 872·5	905·26	868·68	835·15	411·48	307·85	271·27	237·74
25th February 1965	+ 867·5	868·68	835·15	798·58	411·48	307·85	271·27	237·74
25th March 1965	+ 864·4	835·15	798·58	765·05	411·48	341·38	307·85	237·14
10th April 1965	+ 868·6	868·68	835·15	765·05	448·06	411·48	307·85	237·74
25th April 1965	+ 871·3	905·26	868·68	835·15	411·48	307·85	271·27	237·74
10th May 1965	+ 879·8	938·78	798·58	765·05	481·58	448·06	341·38	307·85
25th May 1965	+ 884·2	938·78	798·58	765·05	481·58	448·06	341·38	307·85
10th June 1965	+ 887·5	938·78	868·68	798·68	481·58	411·48	307·85	271·27
25th June 1965	+ 882·2	835·15	798·58	765·05	448·06	411·48	377·95	307·85
10th July 1965	..	835·15	798·58	765·05	448·06	411·48	377·95	307·85
25th July 1965	+ 864·2	798·58	765·05	728·47	411·48	341·38	307·85	237·74
10th August 1965	+ 882·8	798·58	765·05	728·47	411·48	341·38	307·85	237·74
25th August 1965	+ 866·0	798·58	765·05	728·47	411·48	341·38	307·85	237·74
10th September 1965	+ 856·6	765·05	728·47	694·94	377·95	341·38	307·85	271·27
25th September 1965	+ 848·7	765·05	694·94	658·37	341·38	307·85	271·27	237·74
10th October 1965	+ 878·1	938·78	798·58	765·05	481·58	448·06	411·48	307·85
26th October 1965	+ 881·3	938·78	798·58	765·05	481·58	448·06	411·48	307·85
10th November 1965	+ 871·2	905·26	868·68	835·15	411·48	307·85	271·27	237·74
15th November 1965	— 868·9	868·68	835·15	765·05	448·06	411·48	307·85	237·74

TABLE 5—*contd.*

VAIGAI DAM PIEZOMETER READING—1965—*contd.*

	Reservior Level.	*Piezometer number.* 15	16	17	18	10	20	21	22
		Elevation of Piezometer from ground Level. 2	22	23	23	23	23	43	43
		Pore pressure at tip (cms. of water)—cont							
(1)		(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)
10th January 1965	+ 887·2	237·74	167·64	0·0	0·0	0·0	0·0	0·6	0·0
15th January 1966	+ 880·8	237·74	167·67	0·0	0·0	0·0	0·0	0·0	0·0
10th February 1961	+ 872·5	201·17	167·64	0·0	0·0	0·0	0·0	0·0	0·0
25th February 1965	+ 867·5	201·17	167·74	0·0	0·0	0·0	0·0	0·0	0·0
25th March 1965	+ 864·4	201·17	167·64	0·0	0·0	0·0	0·0	0·0	0·0
10th April 1965	+ 868·6	201·17	167·64	0·0	0·0	0·0	0·0	0·0	0·0
25th April 1965	+ 871·3	201·17	167·64	0·0	0·0	0·0	0·0	0·0	0·0
10th May 1965	+ 879·8	237·74	164·64	0·0	0·0	0·0	0·0	0.0	0·0
25th May 1965	+ 884·2	237·72	167·64	0·0	0·0	0·0	0 0	0·0	0·0
10th June 1965	+ 887·5	237·74	167·64	0·0	0·0	0·0	0·0	0.0	0·0
25th June 1965	+ 882·2	237·74	167·64	0·0	0·0	0.0	0·0	0·0	0·0
10th July 1965..	..	237·74	167·64	0·0	6·	0.0	0·0	0·0	0·0
25th July 1965	+864·2	201·17	167·64	0·0	0·0	0·0	0·0	0·0	0·0
10th August 1965	+882·8	201·17	167·64	0·0	0·0	0·0	0·0	0·0	0·0
25th August 1965	+865.0	201·17	167·64	0·0	0·0	0·0	0·0	0·0	0·0
10th September 1965	+856·6	237·74	167·64	0·0	0·0	0·0	0·0	0·0	0·0
25th September 1965	+848·7	167·64	131·06	0·0	0·0	0·0	0·0	0·0	0·0
10th October 1965	+878·1	237·14	131·06	0·0	0·0	0·0	0·0	0·0	0·0
26th October 1965	+881·3	237·14	131·06	0·0	0·0	0·0	0·0	0·0	0·0
10th November 1965	+871·2	201·17	131·06	0·0	0·0	0·0	0·0	0·0	0·0
5th November 1965	+868·9	201·17	131·06	0·0	0·0	0.0	0·0	0·0	0·0

APPENDIX I

VAIGAI DAM.

1. Quantity of masonry up to drainage gallery in the front face of the dam—Non-spillway portion.

Total length of masonry dam..	1,035′ 0″ 3,15·488 m.
Length of spillway	1,01·083
Legnth of non-spillway	2,14·385m.

Average foundation level of non-spillway +822·00.

There is a batter of 1 in 20 from +886·00 level to the foundation level +822·00 level.

(*a*) Width of masonry dam in front of the drainage gallery at foundation level—

Width 15′+64/20 : 15′+3·2′ : 18·2 ft. (5·548 m.).

(*b*) Width of masonry in front of the drainage gallery at the being portion of porous blocks average level +850·00.

(*c*) Width of masonry in front of the porous blocks from 883·00+916·00 (M.W.L.) is 9′0″ (2.7432 m.).

(*d*) Triangular bit in the foot of the dam in front side is 15′×15′ (4·572 m. ×4·572 m.).

Quantity of masonry in non-spillway portion :

(*a*) (+822 to 850) 701′0″ $\times\frac{18{\cdot}2'+16{\cdot}8'}{2}\times 28'0''$: 343,400 (9,718·22 M³)

(*b*) (+850 to 886) 701′ 0″ $\times\frac{16{\cdot}8+9'}{2}\times 36'0''$: 325,544 (9,212·9 M³).

(*c*) (+886 to 916) 701′0″ ×9′0″× 30′0″ : 189,270 (5,356·34 M³).

(*d*) Triangular bit at foundation—
701′0″$\times\frac{15'0''}{2}\times 13'0''$: 78,863 (2,230·83 M³).

937,167 (26,721·8 M³.

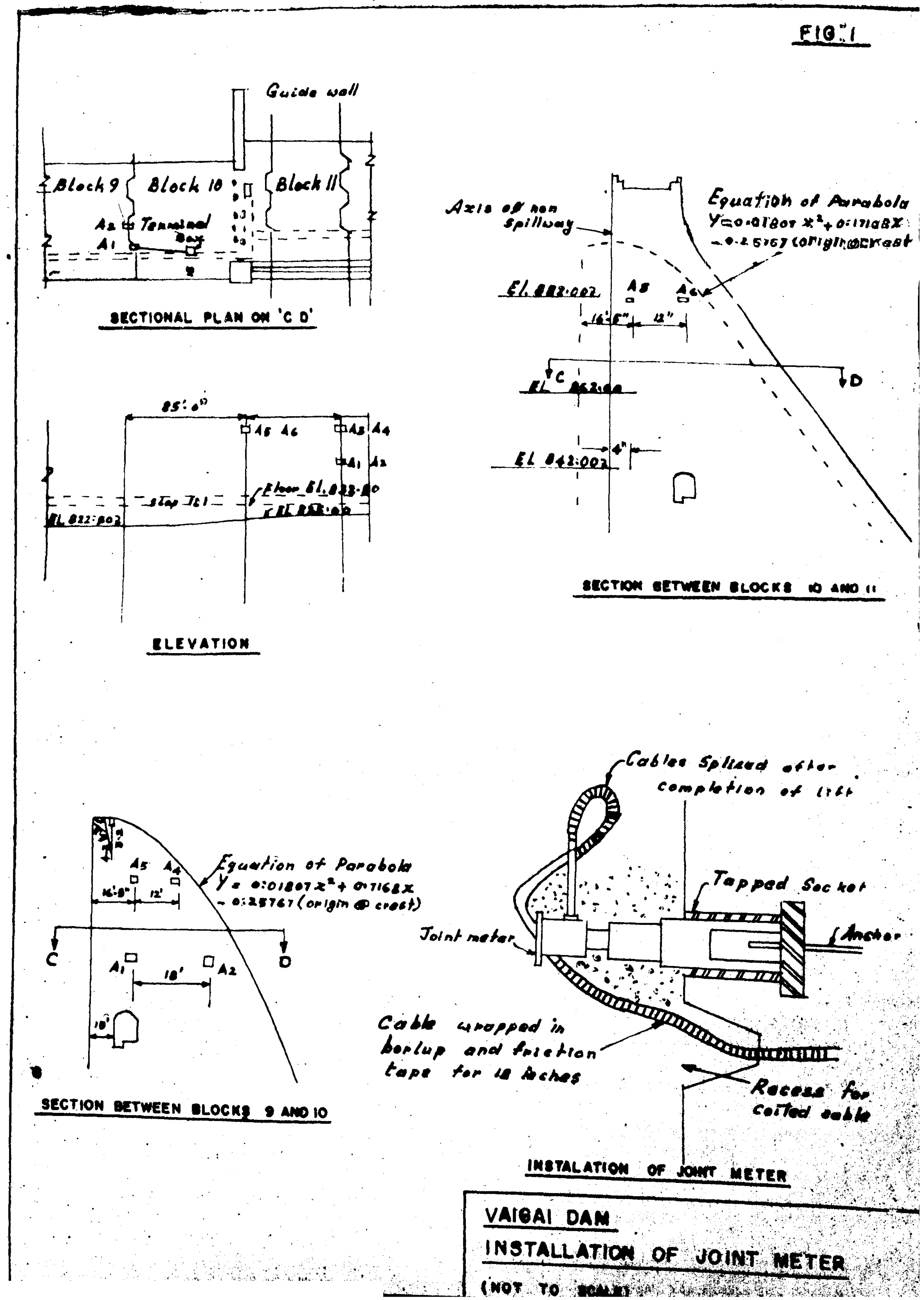
II. *Quantity of masonry infront of the drainage gallery in spillway portion :—*

Average foundation level of the spillway portion+815·00.

(*a*) Width of masonry in front of drainage gallery at foundation level +815·00=16′0″ (4·8768 m.).

(*b*) Width of masonry in front of drainage gallery at the bed of porous blocks +843·00 : 16′ 0″ (4·8768 M.).

(*c*) Width of masonry in front of porous blocks from +843·00 to +901·00 : 9′0″ (2·7432 m.).



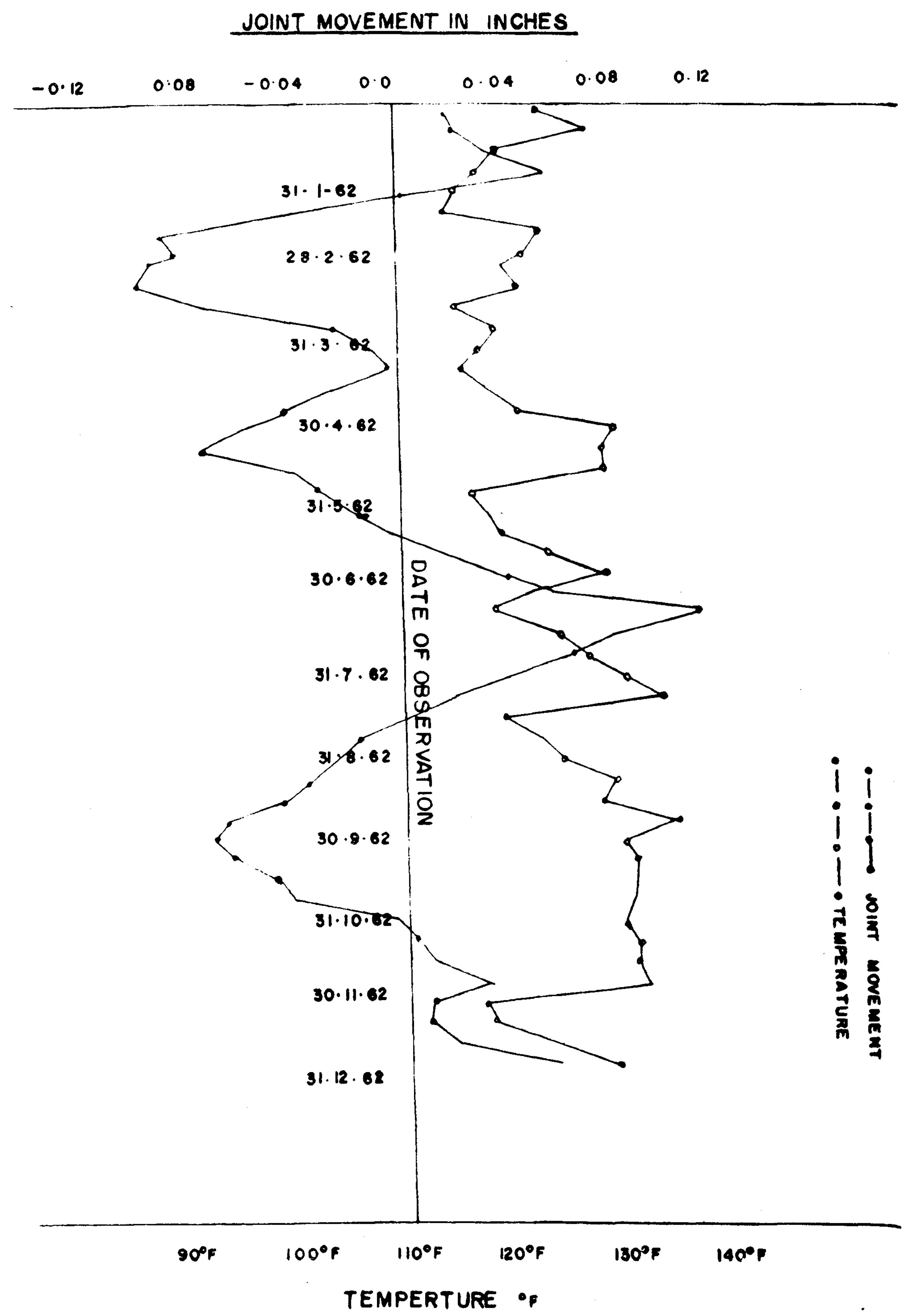


FIG.2. METER No.J3

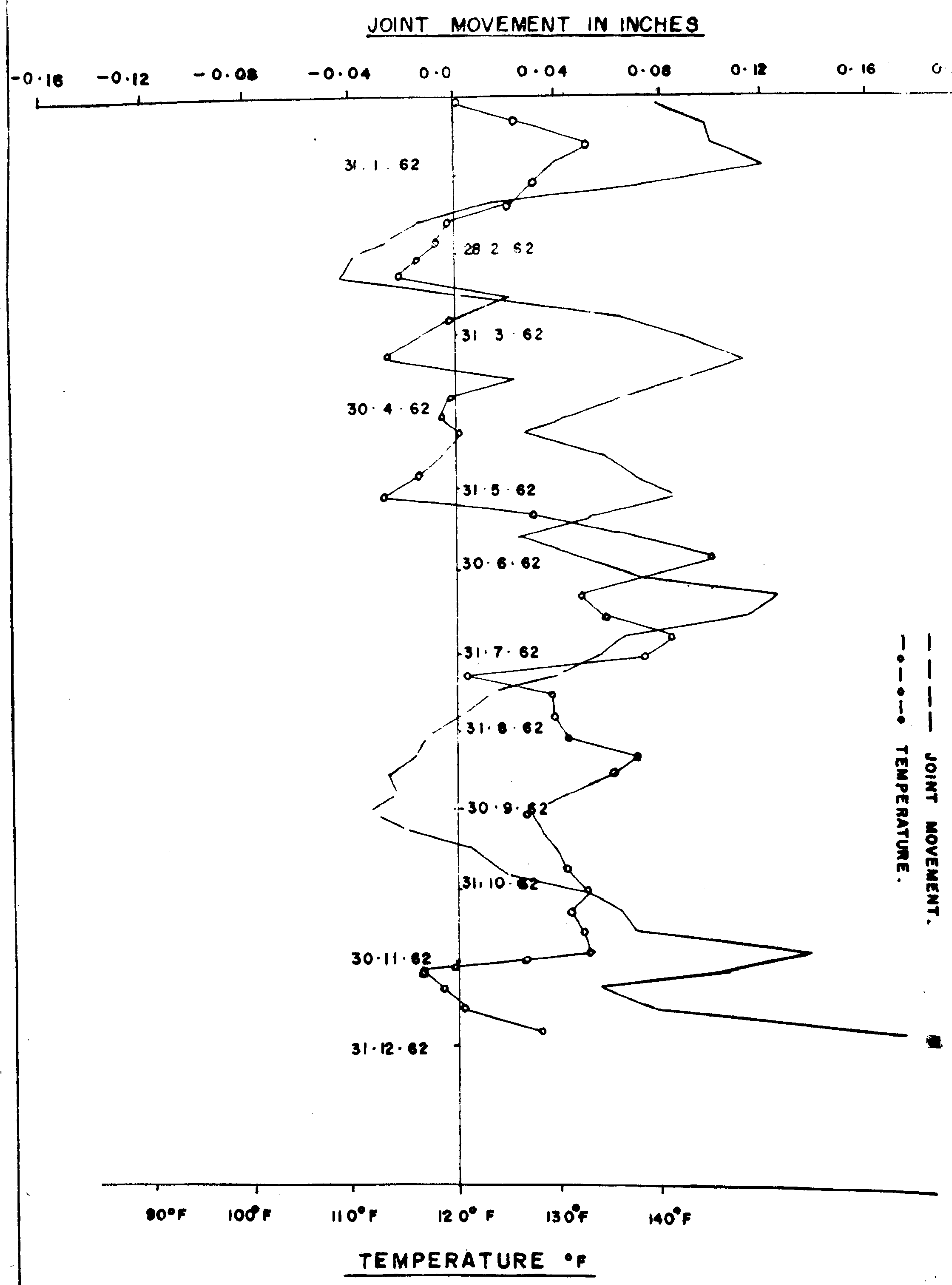


FIG: 3 METER No. J4

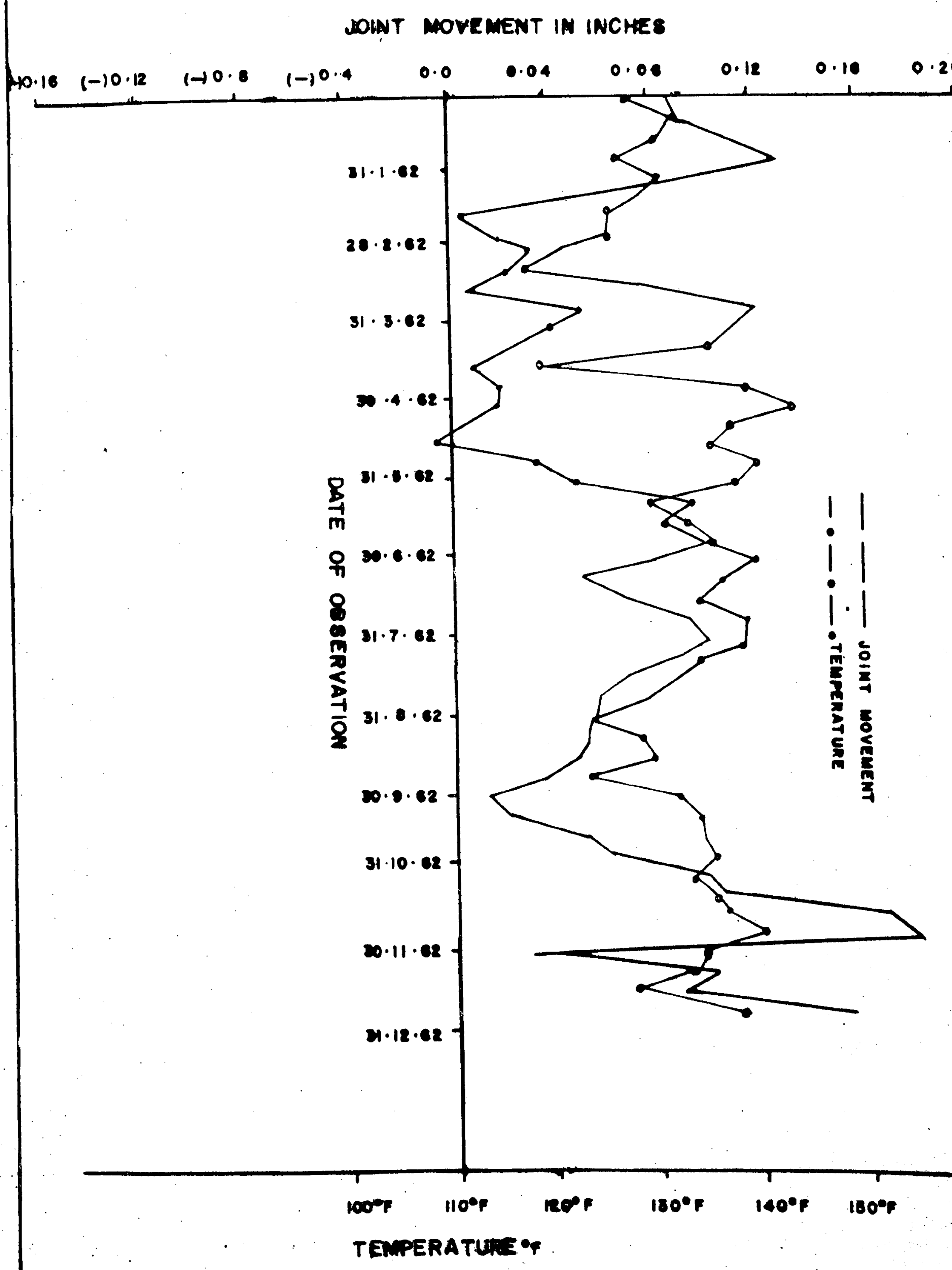


FIG: 4

METER No. J5

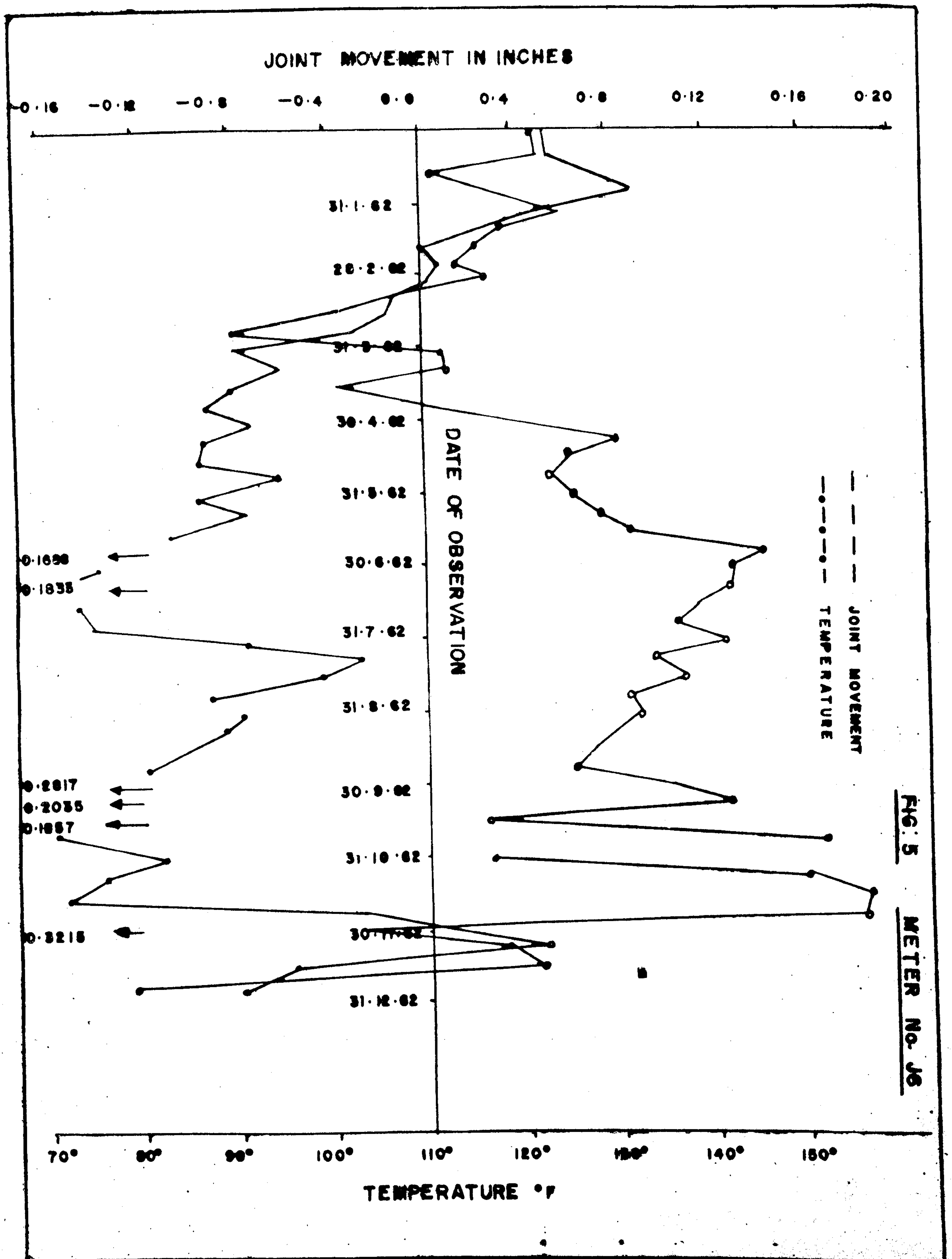
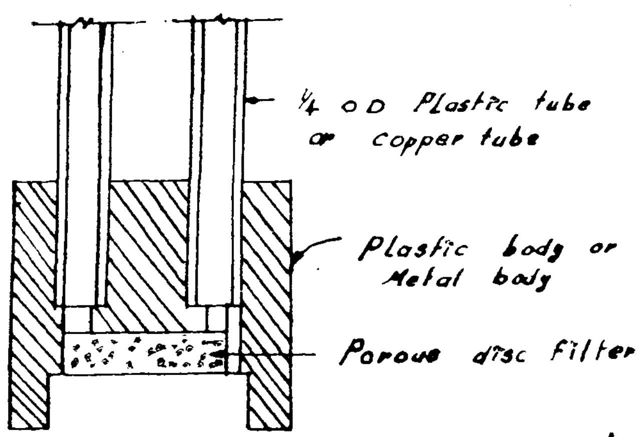
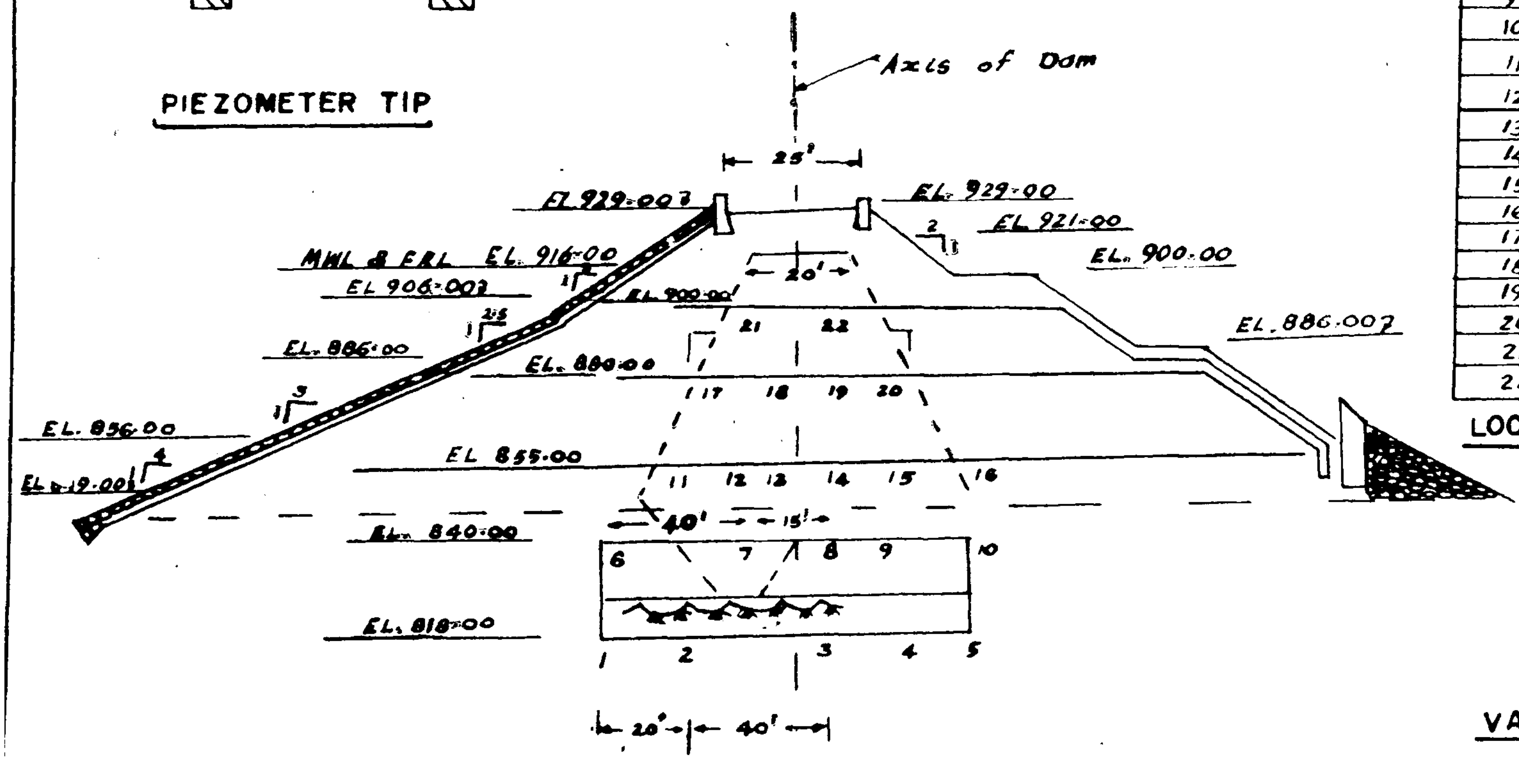


FIG. 5 METER No. J6

FIG: 6



PIEZOMETER TIP



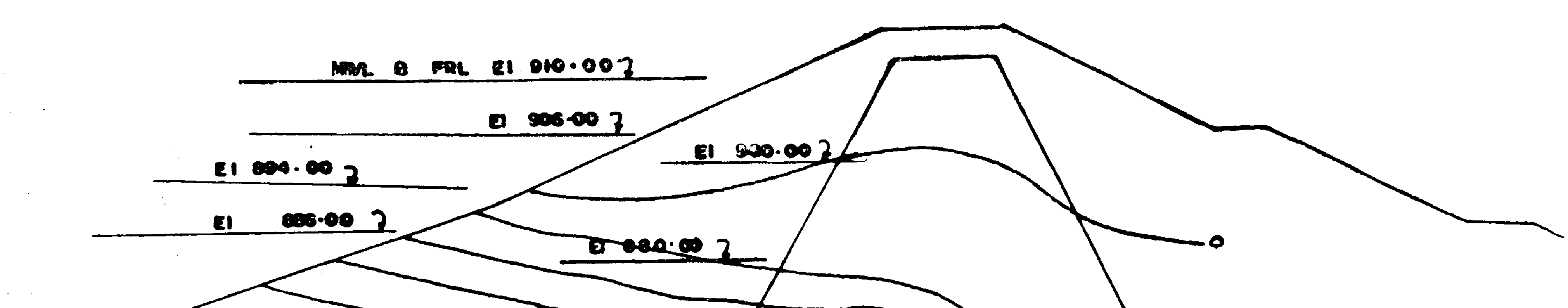
EARTH DAM. L.S.3050

Tip No.	Elevation	Location from Axis of Dam	
1	818.00	55	
2	818.00	35	
3	818.00	–	5
4	818.00	–	25
5	818.00		45
6	840.00	55	–
7	840.00	15	–
8	840.00	–	5
9	840.00	–	25
10	840.00	–	45
11	855.00	40	–
12	855.00	25	–
13	855.00	10	–
14	855.00	–	5
15	855.00	–	25
16	855.00	–	45
17	880.00	25	–
18	880.00	5	–
19	880.00	–	10
20	880.00	–	25.0"
21	900.00	25	
22	900.00	–	5

LOCATION OF PIEZOMETER TIPS

VAIGAI DAM

INSTALLATION OF PIEZOMETER



DATE: 9·1·59.

RESERVOIR LEVEL : 894·00

PORE PRESSURES IN EARTH DAM (Feet of water)

VAIGAI DAM FIG: 7

PIEZOMETER INSTALLATION

EARTH DAM (L.S.3060)

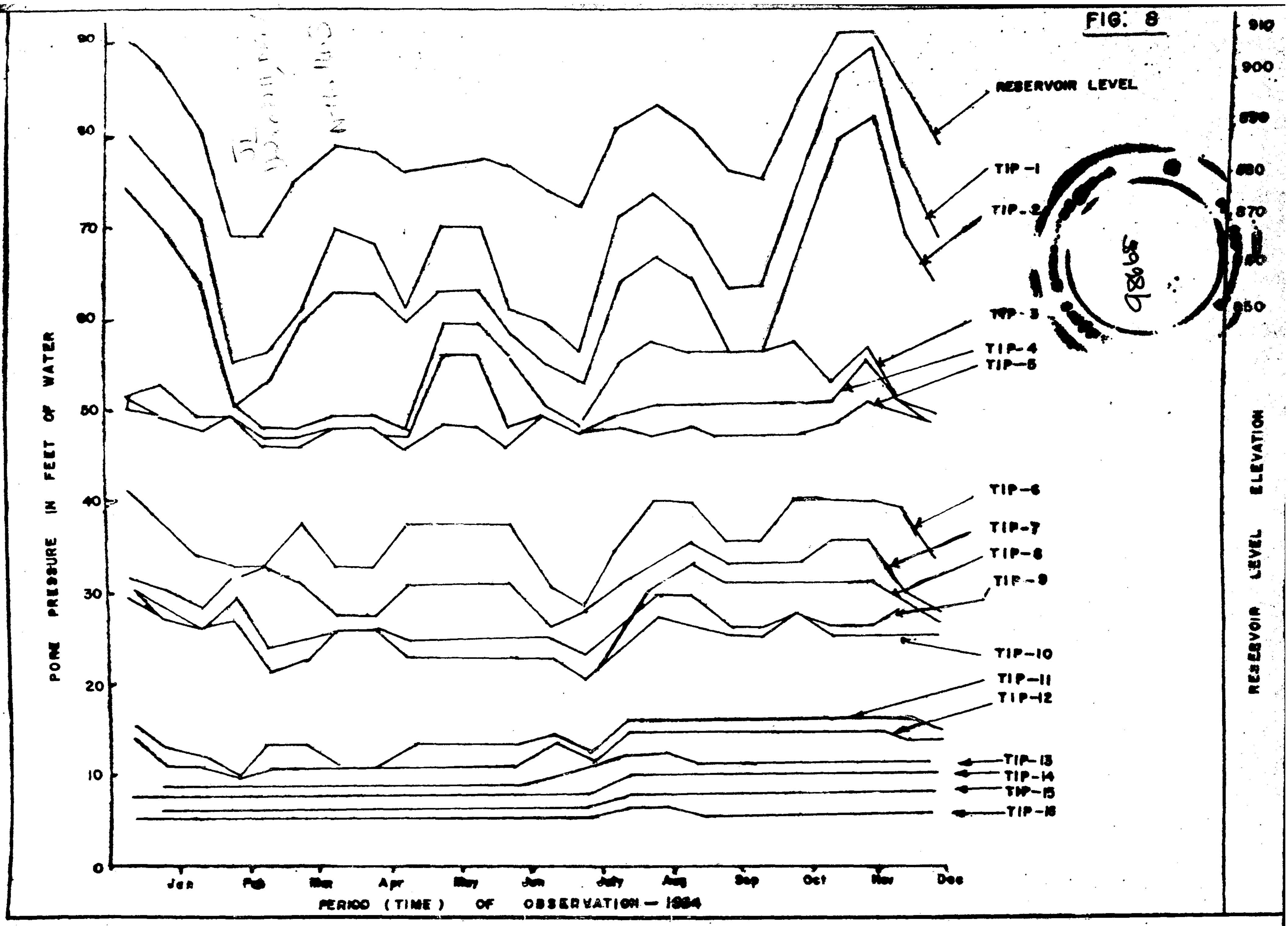


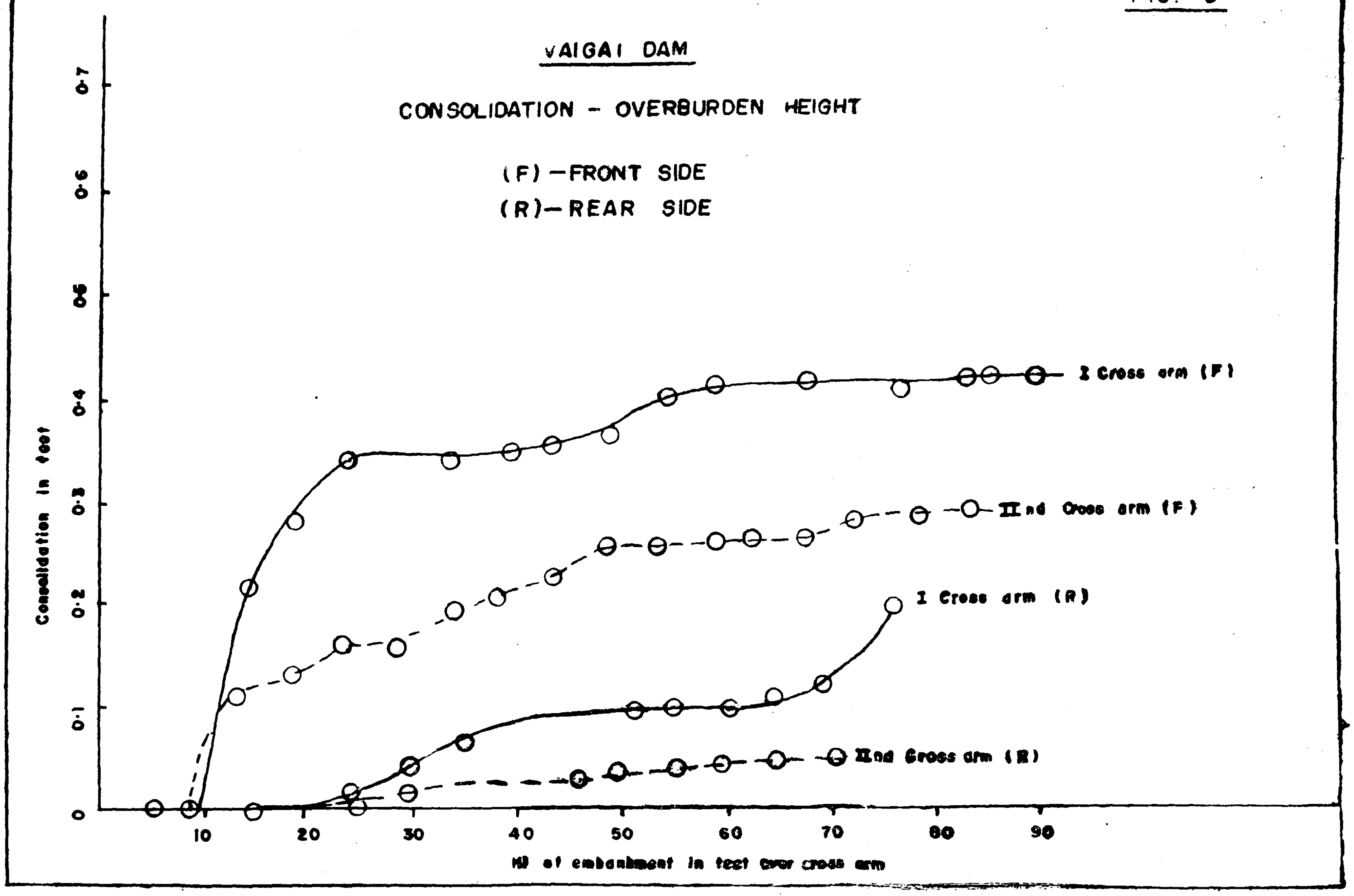
FIG. 8
PORE PRESSURE IN FEET OF WATER
0
10
20
30
40
50
60
70
80
90
Jan
Feb
Mar
Apr
May
Jun
July
Aug
Sep
Oct
Nov
Dec
PERIOD (TIME) OF OBSERVATION — 1964
RESERVOIR LEVEL
TIP-1
TIP-2
TIP-3
TIP-4
TIP-5
TIP-6
TIP-7
TIP-8
TIP-9
TIP-10
TIP-11
TIP-12
TIP-13
TIP-14
TIP-15
TIP-16
RESERVOIR LEVEL ELEVATION
850
870
880
900
910
98665

FIG. 9

VAIGAI DAM

CONSOLIDATION - OVERBURDEN HEIGHT

(F) — FRONT SIDE
(R) — REAR SIDE



BETTER MANAGEMENT OF WATER RESOURCES.

Water is undoubtedly the key input which will determine the success of our attempts at achieving self-sufficiency in foodgrains. Although, since independence, we have put in considerable effort and investment in husbanding our water resources, there have been certain critical gaps in our water management systems which have resulted in misutilisation of our resources. Some of these gaps were pinpointed in an interview at Bangalore recently, by Mr. Sadik Taktsoz an expert and international consultant in water resource management, who is currently Programme Officer, Water and Land Resources Programmes of the Ford Foundation in New Delhi.

Mr. Toktsoz is very familiar with the problems encountered by developing countries in their attempts to come to grips with the complex ramification of water resource management. He has worked as a consultant in Turkey (his home country), Colombia, Pakistan, Phillippines and Thailand, besides doing research in this discipline in the United States of America. He has been in India for over five years now, during which period he has made a thorough study of the Ganga Basin System.

A major deficiency.—According to Mr. Toksoz, one of the major deficiencies in water use systems in India is the inadequate attention paid to utilisation of irrigation water at the farm level. The field channel systems are neglected or hapazardly planned. It is also a fact that the development of the command area under any irrigation project is, in almost all cases, an after-thought. The obvious result is that the actual potential of our irrigation projects is rarely realised. In addition water use is far from optimal, with the farms near the reservoirs wasting water and the farms at the tail end of the canals being starved of water. It is only in the Tahwa Project in Madhya Pradesh, now under construction, that the command area has first been prepared to receive the water, with the field channel system, consolidation of land holdings, etc., being completed, before completion of work on the reservoir and canals.

According to Mr. Toksoz, most of the present concepts of water use and management flowed to the rest of the world from two organisations in the U.S., namely, the U.S. Bureau of Reclamation and the U.S. Department of Agriculture. An inherent mistake made in this technology transfer was the assumption that water management and technology can be set around the Departments of Agriculture of the receiver countries. It was a mistake because those Departments of Agriculture were not manned by engineers but by biological scientists who would not be able to grasp the engineering intricacies involved in planning and executing irrigation systems. Another flow in the technology transfer was that the U.S. systems were engineered for the big holdings of that country. They are not suitable for the very small size holdings in a country like India.

It is, therefore, better that the water use mangement be in the hands entirely of the Irrigation Department, and this includes the field channels and drainage ditches upto the farm level. There is also a need in India for irrigation extension agents, just like the agricultural extension agencies, who can teach the user the proper methods to use irrigation water. Again, even in Indias' irrigation departments, though considerable expertise has been developed in project design and execution, not enough is being done in planning of water use and management.

One of the problems encountered by water system planners in the country is the inadequacy of data. There is a fair sprinkling of rain gauges but hardly any stream gauges. Mr. Toksoz's solution to this is to go in for field hydrological surveys. It is surprising how much information old villagers have crammed in their minds about the flows in streams, rainfall patterns, levels in tanks and wells, etc., over the years, in the vacinty of their villages. This information can be tapped and collected to get fairly accurate hydrological data. Village records also have such information hidden in them. All it needs is dilligent out by patient researchers. The best persons to do such research would be graduate students, in Irrigation and Civil Engineering who would then not only get a practical idea about the scope of water management problems in the country but also be trained to work with solid data instead of blind extrapolations.

Value of minor irrigation.—Mr. Toksoz prefers that India should concentrate more on minor irrigation projects since they need individually smaller investments, can be constructed in short periods, have much less organisational problems than big projects, and, what is more important, mean wider income distribution. In the absence of proper command area development in the big projects, the minor projects ensure more efficient utilisation of water. Another important advantage of small projects is that it is possible to desilt the reservoirs.

Silting, incidentally, is a big problem for Indian reservoirs and has resulted from excessive defoliation of the watersheds. Watershed management is, therefore a top priority exercise if the investment in reservoir based irrigation projects is to be fruitful. Desilting of village irrigation tanks was, once upon a time, being done by the villagers themselves, in Karnataka. But this self-reliance has in the course of time been given up in favour of the usual reliance on the Government. Mr. Toksoz suggested that the villagers can be induced to again take care of the tanks themselves if a portion of the land revenue from each such village is recycled to it for desilting charges.

Mr. Toksoz pointed out that usually minor irrigation projects tend to be located upstream of major ones. This means that the expected water flow into major reservoirs will, with the ensuing years, not materialise. Project designers should take this factor into account.

Exploitation of ground water.—One of the major thrusts on the water use front in India has been and will continue to be the exploitation of ground water. Mr. Toksoz drew attention to the fact that there are already about 7 million wells and 1 million tube wells in India. Abouthalf of the open wells have pumpsets, diesel or electric, installed for lifting the water. By the turn of the century, the number of pumpsets in operation will be around 16 millions. Since the pumpsets have an average life of around 8 years, it means that in the next 10 years, the replacement rate alone of pumpsets will have mounted to about 1 million pieces a year, which may cost about Rs. 400 crores. So, credit agencies in the country should be geared for this huge demand for replacement of pumpsets, in addition tots' purchase of new ones.

Due to the shrinking ceilings on agricultural land holdings one of the peculiarities of pumpset operations in India is that they are grossly under-utilised, on an average about 800 hours a year, which is not even 10 per cent of the number of working hours available. The test method of remedying this situation according to Mr. Toksoz, is to promote community pumping of water. In other words the pumpset owner should be encouraged to sell pumped water to his less affluent neighbours.

When asked to comment about the utilisation of the 400 million acre feet per year flow in the Ganga river basin, 80 per cent of which now drains into the sea Mr. Toksoz said that best method would be to operate a gigantic water cycle in which about 40 million acre feet of water is pumped out of underground acquifers during the lean flow months and these same acquifers are recharged during the flood of the monsoon months. About 3,000 to 4,000 megawatts of power will be required to operate this cycle. This will not be much compared to the total power generation in India by the time all the wells of this water cycle are in operation, which may be about 20 years from now. This same installed power can be used to drivep art of the excess monsoon flow from the Ganga basin to the Cauvery basin, over the Vindhyas, via the suggested Ganga Cauvery canal. This is possible because the wells will not be in operation during the monsoon months.

As regards the Dastur plan of having a garland canal along the Himalayan foothills to collect the runoff during the monsoons, Mr. Toksoz doubted its feasibility because of the danger of the canal filling up fast, with silt eroded from the now denuded hills.

Not much research was being done in the country's, academic institutions on water resource management according to Mr. Toksoz. There was also a communication gap between the academicians and the irrigation departments. Mr. Toksoz advised that research in this field should be done on a practical basis, with the co-operative efforts of both the academicians and the irrigation department people. There was also need to carry the findings to the people who are ultimately concerned--the farmers. Here again, media men are required who can break down scientific abstrusions into every day language which can be followed by the common peasant. Incidently, there is also need for scientists to talk to villagers whose innate wisdom can be of substantial help in directing the reserach.

Ford Foundation's Interest.—Talking about the Ford Foundations' interest in promoting studies on water resources management in India, Mr. Toksoz said there were now four on going projects, one each at the Water Technology Centre of I.A.R.I., Delhi, the Central Soil and Water Conservation Research and Training Institute. Dehra Dun, the University of Roorkee and I.I.T., Kharagpur, Roorki and I.I.T., Kharagpur have started courses in the Economics of Water Resources Engineering.

Bangalore has a good chance of setting a Ford Foundation grant for research in this discipline, since it has reputed engineering and social sciences institutions like the Indian Institute of Science, the Indian Institute of Management and the Institute for Social and Economic Change, Most probably the grant will be for a multi-institutional project with field emphasis.

Courtesy from the Hindu—6th March 1976.

A PEEP INTO PHOTOGRAMMETRY.

BY

THIRU M. SADASIVAM, M.E., M.I.E., M.S.T.E. (INDIA), M.S.P. (AMERICA) M.P.S. (ENGLAND).*

1. *Definition.*—Photogrammetry is the science and/or art of obtaining reliable measurements from photographs It is both qualitative (otherwise called photographic interpretation) and quantitative (usually called photogrammetry).

2. *Classification.*—Photogrammetry is either aerial or terrestrial, distant or close-up, mono or stereo, topographic or non-topographic. It is applicable if the object photographed and studied is very large as the earth's surface, very small as a sand particle, moving as a missile, changing as a hydraulic phenomenon, inaccessible as an atomic particle in a cloud chamber, complicated as a deformed human body..........and infinitum.

3. *Development.*—Born as a terrestrial science, photogrammetry, later, took to air. It was Laussedat who first compiled topographic maps of Paris from photographs taken from the ground in 1849, and later from balloons in 1858. Many continental countries, e.g. Germany, Switzerland, Austria, Italy, France, have developed this subject of photogrammetry considerably and have reaped rich dividents. Though America started a little late in applying photogrammetry, who took swift and giant strides, especially during the past 3 or 4 decades, specialising in photographic interpretation. England, unfortunately took a passive interest in it, and as late as 1935, a committee which went deep into it, advocated against its advent. As Prof. Oswal, an Indian photogrammetrist, has said, "It cost England another world war to discover the error and the result is that she is forty years behind Europe in the field". India also toed the same line and only after her independence, she gave a second thought to it, and had recorded a fairly good progress during the past 20 years.

4. *Major application.*—Topographic mapping is, by far, the most widely benefited area. But more important is the military sphere, both for defence tactics and offence manoeuvres. Von Fristsch, a German General, said in 1938 that "the nation with the best photographic reconnaissance will win the war". The Axis Powers were superior for in this arena from 1939 to 1942 and hence had initial successes but later the Allies stole a march over their enemies with the result the Second World War took a different turn.

Name any field and photogrammetry can play an useful role in it. Earth sciences natural resources inventories, engineering facilities all have contributions from this subject. Even in nontopographic field photogrammetry had helped medicine, criminology motion studies, sculpture, astronomy, architecture, structural studies, hydraulisc, teaching, etc.

This is not to mean that photography is an end in itself. It is only a means to an end. It only supplements, and not supplants, conventional ground survey methods. But still, one can only ill-afford to neglect it altogether.

5. *Stereoscopy.*—The foundation on which the huge edifice of photogrammetry rests is Stereoscopic vision, otherwise called Binocular Effect. It is because of this that objects are seen in three dimensions. While two eyes contribute to this 3rd dimension of depth (or distance), two photographs of an object or object space alone can make the observer study them stereoscopically and gather a fund of information. The importance of the 3rd dimension needs no emphasis. Photogrammetry will loose much of its charm and efficacy but for stereoscopy.

6. *Conclusion.*—Mott says that "there can be few major engineering projects anywhere in the world in which air photography does not play a vital part". Hard feels that "from time to time in history, science has provided mankind with excitement and new vision. These are not necessarily occasions of basic discoveries but of disclosure. which touch the imagination. The world became new with the telescope, the microscope and with X-rays. Today, it seems, we are in such a phase of history Reading observes that "there are vast areas in the world today, hungry for the improvements available through the application of the modern sciences. Photogrammetry can do more than any other science to expedite these improvements and to make sure they are carried out with a minimum of false starts and wasted effort"

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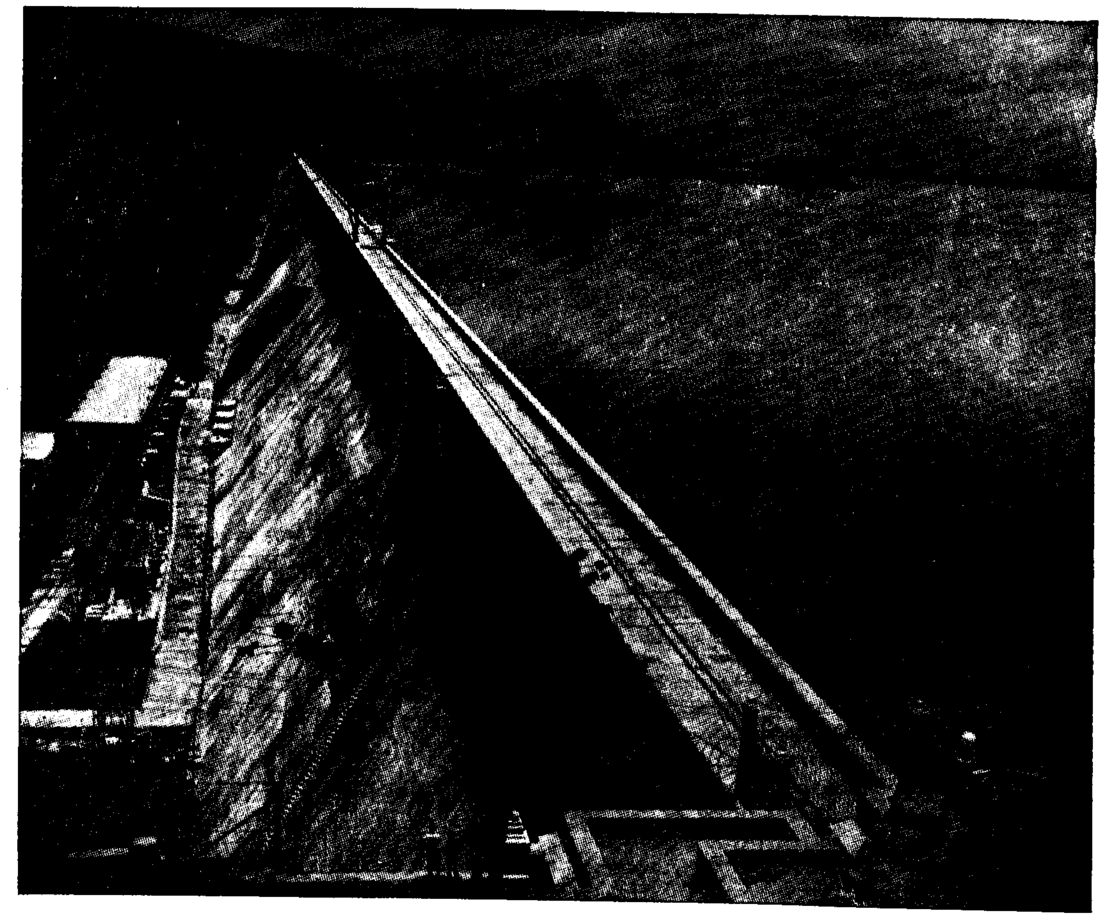
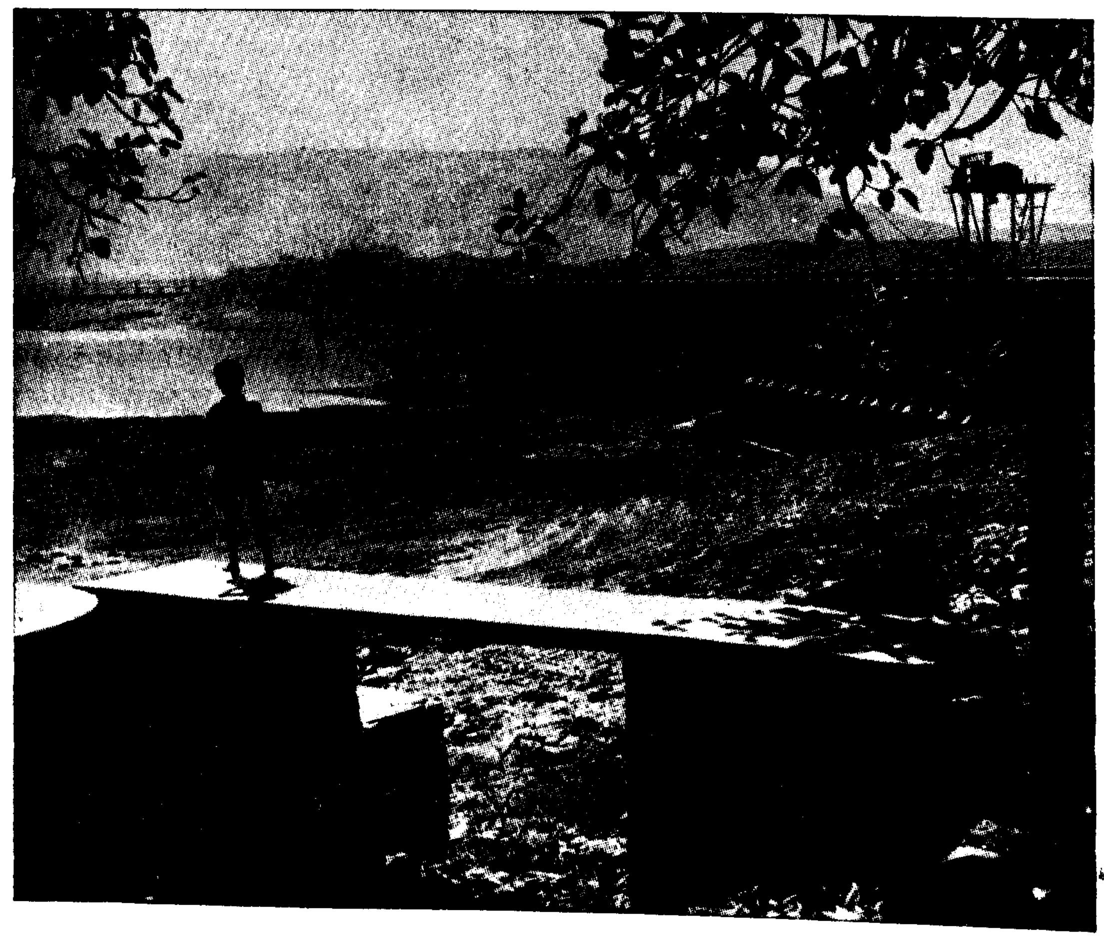
*Assistant Professor of Civil Engineering College of Engineering, Guindy, Madras.

From the lecture given in the Building Centre Dn., P.W.D., Madras.

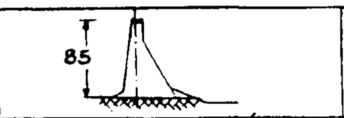
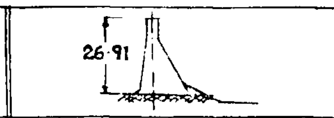
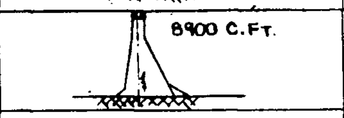
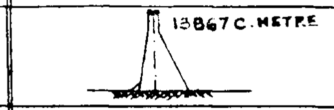
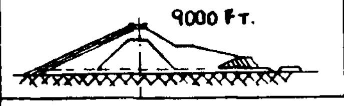


Mettur Dam—At full level.



Mettur Dam—At low level.

TUNACADAVU DAM (P.A.P)

MAXIMUM HT. OF DAM	 85	 26·91	MAXIMUM HT. OF DAM
MASONRY QUANTITY	 8900 C.FT.	 13867 C.METRE	MASONRY QUANTITY
EARTH DAM QUANTITY	 9000 FT.	 23470 METRE	EARTH DAM QUANTITY
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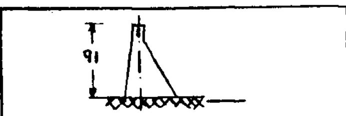
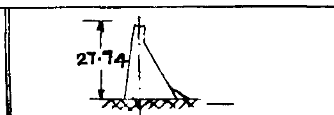
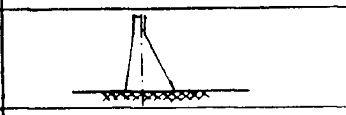
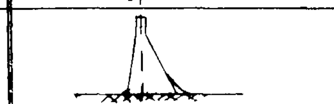
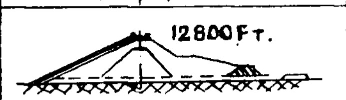
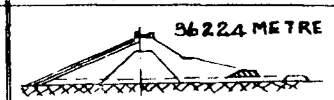
MAXIMUM HT. OF DAM	 91	 27·74	MAXIMUM HT. OF DAM
MASONRY QUANTITY			MASONRY QUANTITY
EARTH DAM QUANTITY	 12800 FT.	 36224 METRE	EARTH DAM QUANTITY
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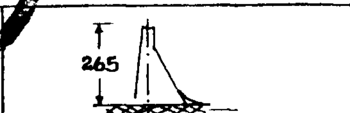
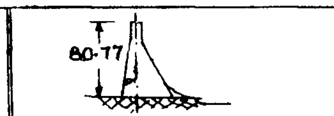
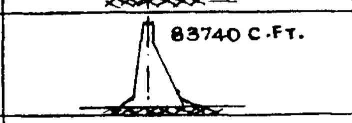
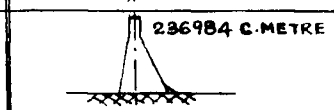
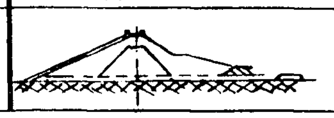
MAXIMUM HT. OF DAM	 265	 80·77	MAXIMUM HT OF DAM
MASONRY QUANTITY	 83740 C.FT.	 236984 C.METRE	MASONRY QUANTITY
EARTH DAM QUANTITY			EARTH DAM QUANTITY
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