The results of these experiments showed

(*i*) That Sharma's formula gave incorrect results for values of "*H*" exceeding 2'.

(*ii*) For values of "*H*" exceeding 2' Crump's formula is most suitable. I adopted a co-efficient of 7·5 in this formula ($q = c\ by\ \sqrt{h}$) as most of the outlets in the East Circle have "*b*" equal to 0·2' or 0·25'. The statement shows that the mean value of the co-efficient for these two sizes is 7·6.

(*iii*) For values of "*H*" less than 2' the co-efficient in Crump's formula increases very rapidly. Sufficient observations were not carried out to obtain the correct co-efficient, so I adopted Sharma's formula [$q = K\ b\ (H^{\frac{3}{2}} - h^{\frac{3}{2}})$] as most of Sharma's experiments in Sargodha were carried out with the lower values of "*H*", and his formula gave correct results for such values.

(*iv*) The experiments showed that the minimum-modular head, calculated by Sharma's method, is correct. This method of calculating the minimum modular head involves the use of an elaborate table, a copy of which I do not propose to reproduce in this paper. Blue prints can be obtained from the East Circle.

Statement showing average values of "c" in the formula $q = cb\,y\sqrt{h}$ *for Sharma's modification of the A. P. M. Outlet.*

H	y						Remarks
	0·4	0·5	0·8	1·0	1·2	Average	
			$b = 0{\cdot}2$				
1·5	8·2	8·3	8·3	...	...	8·3	Average = 7·6
2·0	7·7	7·6	7·8	7·7	7·8	7·7	
2·5	7·8	7·8	7·9	7·7	7·4	7·7	
3·0	7·5	7·5	7·4	7·1	7·3	7·4	
3·5	8·1	7·5	7·6	7·1	7·1	7·5	
			$b = 0{\cdot}25$				
2·0	7·8	7·9	8·1	8·1	8·2	8·0	Average = 7·6
2·5	7·6	...	7·6	...	7·6	7·6	
3·0	7·6	...	7·5	7·2	7·6	7·5	
3·5	...	7·5	7·2	...	7·2	7·3	
			$b = 0{\cdot}32$				
1·5	8·1	8·4	8·5	...	..	8·3	Average = 7·7
2·0	7·9	7·9	8·0	8·2	8·3	8·1	
2·5	7·9	7·8	7·8	7·5	7·5	7·7	
3·0	8·0	7·9	7·7	7·6	7·5	7·7	
3·5	7·8	7·6	7·5	7·4	7·4	7·5	
			$b = 0{\cdot}5$				
1·5	7·9	8·2	...	...	...	8·0	Average = 7·8
2·0	7·9	7·8	8·0	8·3	...	8·0	
2·5	8·0	7·9	7·9	7·9	7·8	7·9	
3·0	7·9	7·9	7·9	7·7	7·6	7·8	
35	7·9	7·9	7·9	7·6	7·5	7·7	

APPENDIX C.

Statement showing percentage variation in discharge of A. P. M. Outlets for a rise of 0·3′ in the water level in the distributary.

H	y	Discharge	H	y	Discharge	Difference Col. 6 – Col. 3	Percentage variation in Discharge $\frac{\text{Col. 6} - \text{Col. 3}}{\text{Col. 3}} \times 100$	
				$b = 0·2$				
1·5	0·4	0·61	1·8	0·4	0·69	0·08	13	Average = 19
	0·8	0·98		0·8	1·17	0·19	19	
	1·0	1·03		1·0	1·30	0·27	26	
2·0	0·4	0·74	2·3	0·4	0·81	0·07	10	Average = 14
	0·8	1·28		0·8	1·43	0·15	12	
	1·0	1·46		1·0	1·66	0·20	14	
2·5	0·4	0·85	2·8	0·4	0·91	0·06	7	Average = 8
	0·8	1·53		0·8	1·65	0·12	8	
	1·0	1·79		1·0	1·96	0·17	9	
3·0	0·4	0·94	·3	0·4	0·99	0·05	5	Average = 6
	0·8	1·75		0·8	1·85	0·10	6	
	1·0	2·06		1·0	2·21	0·15	8	
3·5	0·4	1·03	3·8	0·4	1·07	0·04	4	Average = 5
	0·8	1·92		0·8	2·02	0·10	5	
	1·0	2·30		1·0	2·44	0·14	6	
				$b = 0·25$				
1·5	0·4	0·76	1·8	0·4	0·86	0·10	13	Average = 19
	0·8	1·22		0·8	1·46	0·24	19	
	1·0	1·29		1·0	1·63	0·34	26	
2·0	0·4	0·92	2·0	0·4	1·01	0·09	10	Average = 12
	0·8	1·60		0·8	1·79	0·19	12	
	1·0	1·83		1·0	2·08	0·25	14	
2·5	0·4	1·06	2·5	0·4	1·13	0·07	7	Average = 8
	0 8	1·90		0·8	2·06	0·16	8	
	1·0	2·24		1·0	2·45	0·21	9	
3·0	0·4	1·18	3·3	0·4	1·24	0·06	5	Average = 7
	0·8	2·16		0·8	2·31	0·15	7	
	1·0	2·58		1·0	2·77	0·19	8	
3·5	0·4	1·28	3·8	0·4	1·34	0·06	5	Average = 6
	0·8	2·39		0·8	2·53	0·14	6	
	1·0	2·89		1·0	3·05	0·16	6	

APPENDIX D.

Revised discharge Table for Portable Flumes.

Gauge	*Discharge.* Flume width 1·0′	*Discharge.* Flume width 1·5′
0·16	0·22	0·30
0·18	0·25	0·36
0·20	0·28	0·42
0·22	0·32	0.49
0·24	0·37	0·56
0·26	0·42	0·64
0·28	0·47	0·72
0·30	0·53	0·80
0·32	0·59	0·89
0·34	0·65	0·98
0·36	0 71	1·07
0·38	0·78	1·17
0·40	0·85	1·27
0·42	0·92	1·37
0·44	0·99	1·47
0·46	1·06	1·57
0·48	1·13	1·67
0·50	1·20	1·78
0·52	1·28	1·90
0·54	1·36	2·03
0·56	1·44	2·16
0·58	1·53	2·29
0·60	1·62	2·42
0·62		2·56

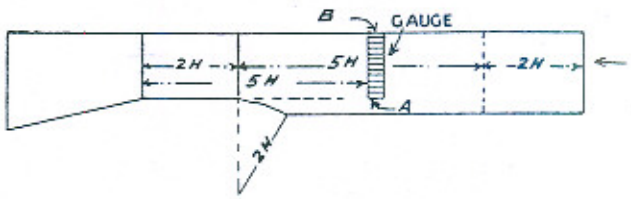
INSTRUCTIONS.

(1) Fix flume in bed of watercourse at least two chains from outlet, and in a reach where the watercourse is straight. The outlet must be closed before the flume is fixed.

(2) Level the crest of the flume in both directions with a spirit level.

(3) Fill sand or a mixture of sand and clay behind the sides of the flume. Do not ram the filling as, if this is done, the flume will be damaged.

(4) Let in a small quantity of water, and close off when the water just starts to spill over the crest. Then read the gauge at the downstream edge AB.



(5) Open the outlet fully and allow the full discharge to flow through the flume for at least 5 minutes. When gauge is steady read it again at the downstream edge.

(6) Take the difference between the gauge readings obtained *vide* paragraphs 4 and 5 above, and apply it to the discharge table opposite and read off the discharge.

(7) Precautions to be taken when setting the portable flume.

(*a*) See that there is a defined standing wave both below the outlet and below the flume. To obtain a wave below the flume it may be necessary to escape water, which has passed over the flume, into borrow pits or low ground.

(*b*) The gauge reading for the 1′ wide flume should not exceed 0·6′.

(*c*) Fix the flume so that the water level in the watercourse upstream of the flume will be approximately the normal level in the watercourse.

Gauge	*Discharge.* Flume width 1·0′	*Discharge.* Flume width 1·5′	Instructions.
0·64		2·70	(8) To prevent damage to the flume carry it on coolies' heads where possible. If the flume gets damaged have it repaired by an experienced mistri.
0·66		2·84	
0·68		2·98	
0·70		3·12	

APPENDIX E.

Statement showing discharges of outlets, and absorption on Awagat Distributary during Augus , 1939.

R. D.	Side.	Designed Data.					Observations in August, 1939.					
		b.	*y.*	*h.*	*q.*	*H.*	*H.*	Discharge calculated from Formula.	Discharge observed with tin flume.	Difference Col. 10 – Col. 9.	Percentage difference $\frac{\text{Col. 11}}{\text{Col. 9}} \times 100$.	Percentage difference $\frac{\text{Col. 11} - \text{Col. 6}}{\text{Col. 6.}} \times 100$.
1	2	3	4	5	6	7	8	9	10	11	12	13
4638	R	0·2	0·73	2·27	1·64	3·00	2·89	1·62	1·71	+0·09	+ 6%	+ 4%
7960	L	0·2	0·47	2·03	1·00	2·50	2·50	1·01	1·08	+0·07	+ 7%	+ 8%
8830	R	0·2	0·76	2·14	1·67	2·90	2·94	1·69	1·42	−0·27	−16%	−15%
10000	R	0·2	0·80	2·10	1·73	2·90	2·95	1·76	1·91	+0·15	+ 9%	+11%
11250	R	0·25	0·70	2·20	1·93	2·90	3·04	2·00	2·05	+0·05	+ 2%	+ 6%
11294	Flume	1·03	...	...	4·25	1·16	1·22	4·62	4·49	−0·13	− 3%	+ 6%
11415	L	0·20	0·53	2·37	1·22	2·90	3·11	1·28	1·23	−0·05	− 4%	+ 1%
11850	L	0·2	0·51	2·39	1·18	2·90	3·07	1·23	1·20	−0·05	− 2%	+ 2%
20176	L	0·2	0·81	1·37	1·44	2·20	2·45	1·56	1·53	−0·03	− 2%	+ 6%
20191	R	0·25	0·88	1·32	1·90	2·20	2·48	2·10	2·11	+0·01	*Nil*	+12%
24665	L	0·2	1·04	1·16	1·68	2·20	2·39	1·81	1·75	−0·06	− 3%	+ 4%
29923	R	0·2	0·72	1·88	1·47	2·60	2·72	1·52	1·59	+0·07	+ 5%	+ 9%
30770	L	0·25	0·86	1·74	2·13	2·60	2·63	2·14	2·05	−0·09	− 4%	− 4%

33202	L	0·2	0·76	1·61	1·44	2·37	2·52	1·52	1·72	+0·20	+13%	+20%
35545	R	0·2	0·47	1·79	0·94	2·26	2·42	0·99	1·22	+0·23	+23%	+30%
40092	L	0·2	0·83	1·37	1·38	2·20	2·19	1·46	1·48	+0·02	+ 1%	+ 8%
43435	R	0·2	0·54	1·56	0·93	2·10	2·19	1·04	1·20	+0·16	+15%	+30%
47815	L	0·2	0·68	1·22	1·15	1·90	2·25	1·28	1·22	−0·06	− 5%	+ 6%
51148	R	0·2	0·68	1·22	1·15	1·90	2·22	1·26	1·30	+0·04	+ 3%	+13%
51170	L	0·25	0·46	1·44	0·96	1·90	2·20	1·14	1·21	+0·07	+ 6%	+26%
53370	L	0·32	0·58	1·32	1·58	1·90	2·02	1·67	1·64	−0·03	− 2%	+ 4%
53927	R	0·20	0·69	1·21	1·17	1·90	1·97	1·11	1·21	+0·10	+10%	+ 4%
56739	L	0·2	0·72	0·98	1·18	1·70	1·76	1·10	1·19	+0·09	+ 8%	+ 1%
57858	L	0·2	0·93	0·77	1·46	1·70	1·87	1·40	1·31	−0·09	− 6%	−10%
59950	L	0·25	0·92	0·78	1·70	1·70	1·82	1·76	1·76	*Nil*	*Nil*	+ 4%
63885	R	0·25	0·72	0·98	1·47	1·70	1·96	1·47	1·48	+0·01	*Nil*	*Nil*
63958	L	0·2	0·77	0·93	1·20	1·70	1·99	1·23	1·22	−0·01	*Nil*	+ 1%
65300	R	0·2	0·50	1·20	0·79	1·70	1·78	0·80	0·80	*Nil*	*Nil*	+ 1%
66728	L	0·2	0·74	0·96	1·11	1·70	1·81	1·14	1·03	−0·11	−10%	− 7%
68010	TL	0·72	...	...	1·27	0·70	0·69	1·23	1·26	+0·03	+ 2%	− 1%
68010	TF	0·92	...	..	1·61	0·70	0·69	1·57	1·60	+0·03	+ 2%	− 1%
				Total ...	45·73			47·51	47·97			

Theoretical Absorption = 10% of 45·73 = 4·57 cusecs.

Discharge at R. D. 1900 (gauge = 1·44 = 56·45 cusecs).

Actual Absorption = 56·45 − 47·74 = 8·71 cusecs = 18% of 47·74 cusecs.

Notes.—1. To obtain the actual absorption the mean of columns 9 and 10 is deducted from 56·45 cusecs.

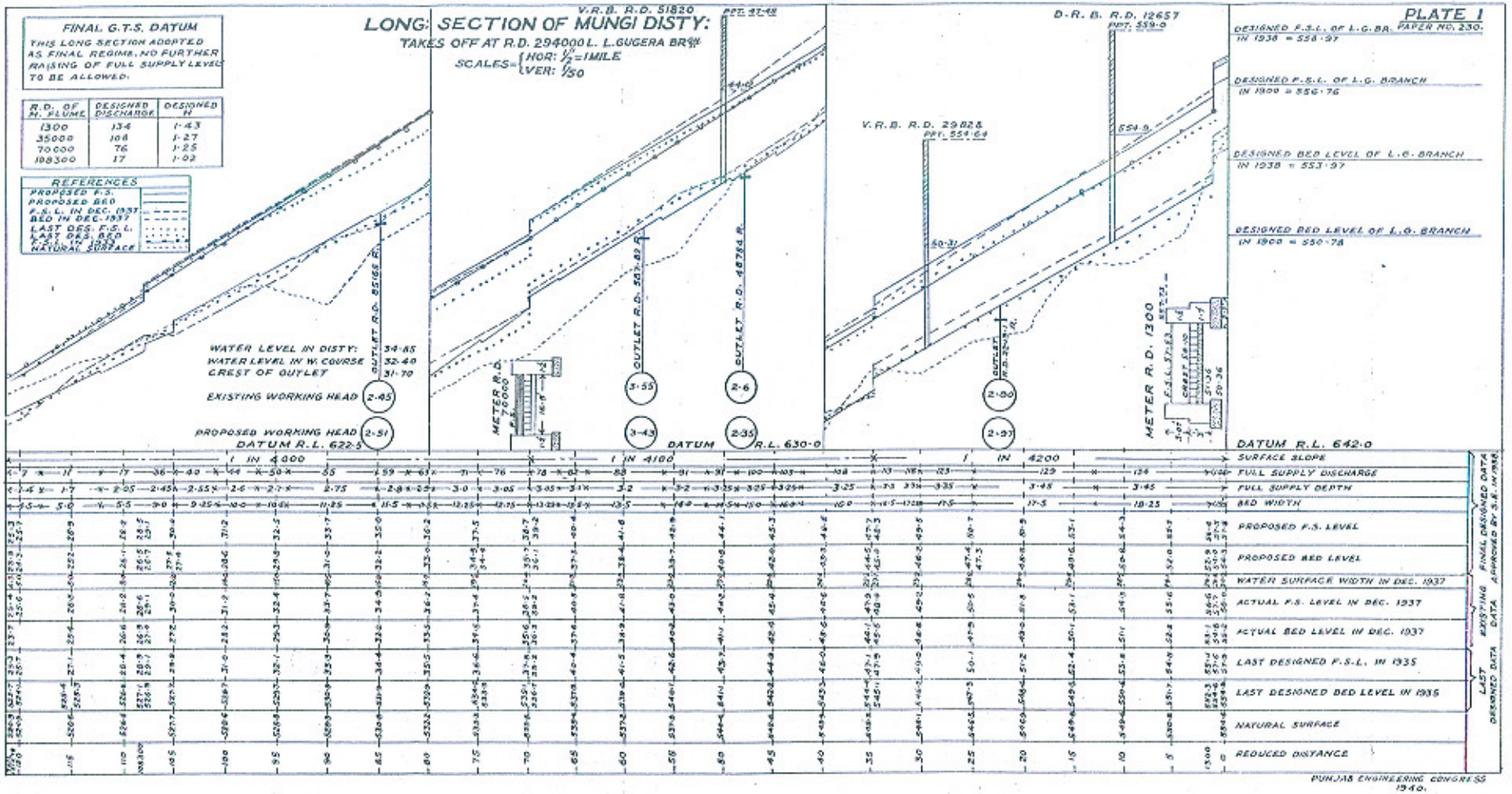
2. The formulæ used for calculating the discharge are :

Where "H" exceeds 2·0′ $q = 7{\cdot}5\ b\ y\ \sqrt{h}$

Where "H" is less than 2·0′ $q = K\ b\ (H^{\frac{3}{2}} - h^{\frac{3}{2}})$.

3. Column 12 gives the percentage difference between the calculated and observed discharges.

4. Column 13 gives the difference between the designed and observed discharges.



PUNJAB ENGINEERING CONGRESS 1940.

LONG. SECTION OF MUNGI DISTRIBUTARY

SHOWING F.S. AND BED LEVELS SINCE CONSTRUCTION

SCALES = { HOR: ½ = 1 MILE ; VER: 1/50 }

FINAL G.T.S. DATUM

REFERENCES

- FULL SUPPLY LEVEL IN 1938
- BED LEVEL IN 1938
- FULL SUPPLY LEVEL IN 1933
- BED LEVEL IN 1933
- FULL SUPPLY LEVEL IN 1916
- BED LEVEL IN 1916
- FULL SUPPLY LEVEL IN 1900
- BED LEVEL IN 1900

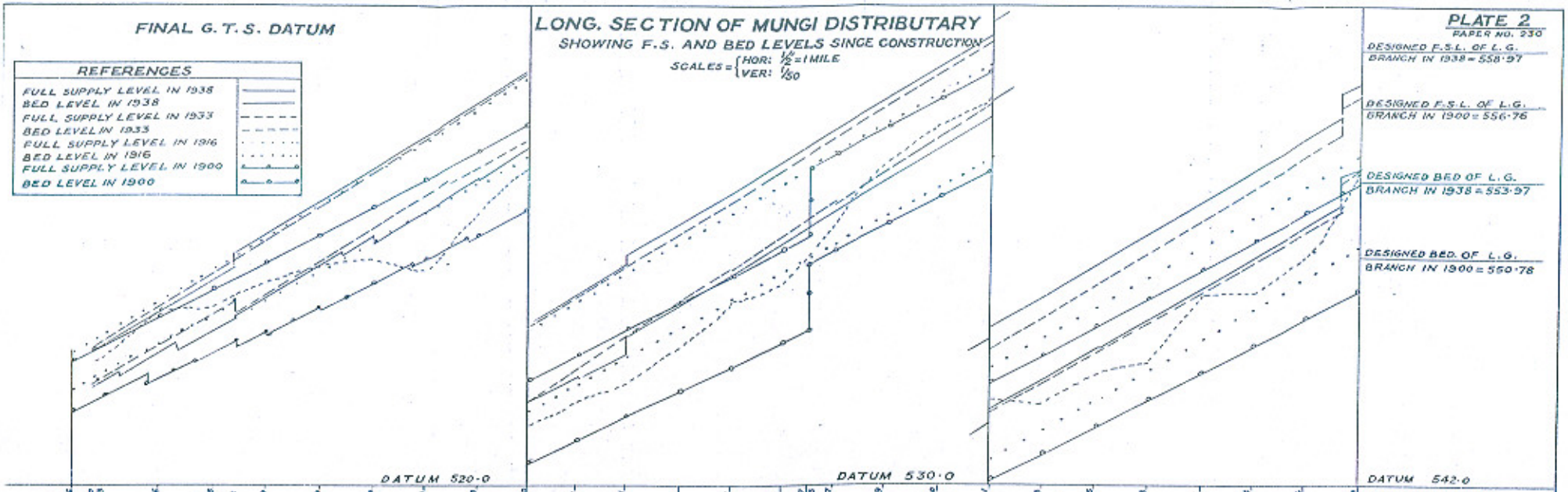


PLATE 2

PAPER NO. 230

DESIGNED F.S.L. OF L.G. BRANCH IN 1938 = 558·97

DESIGNED F.S.L. OF L.G. BRANCH IN 1900 = 556·76

DESIGNED BED OF L.G. BRANCH IN 1938 = 553·97

DESIGNED BED OF L.G. BRANCH IN 1900 = 550·78

FULL SUPPLY LEVEL IN 1900	
BED LEVEL IN 1900	
FULL SUPPLY LEVEL IN 1916	
BED LEVEL IN 1916	
FULL SUPPLY LEVEL IN 1933	
BED LEVEL IN 1933	
FULL SUPPLY LEVEL IN 1938	
BED LEVEL IN 1938	
REDUCED DISTANCE	125 120 115 110 105 100 95 90 85 80 75 70 65 60 55 50 45 40 35 30 25 20 15 10 5 300 0

PUNJAB ENGINEERING CONGRESS 1940

HEAD OF MUNGI AND JANIWALA DISTYS

TAKES OFF AT R.D. 294000 L.G. BRANCH

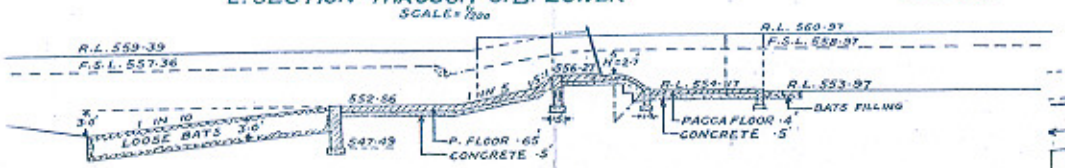
SCALE = 1/200

PLATE 3

PAPER NO. 230

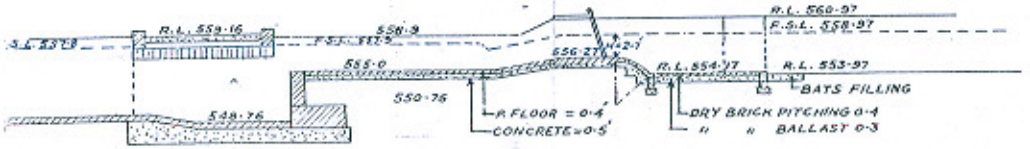
L. SECTION THROUGH G.B. LOWER

SCALE = 1/200



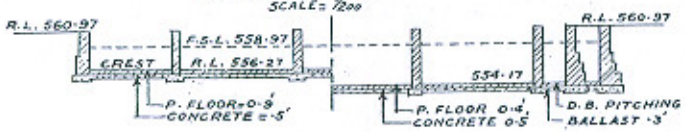
LONGITUDINAL SECTION THROUGH MUNGI DISTY:

SCALE = 1/200



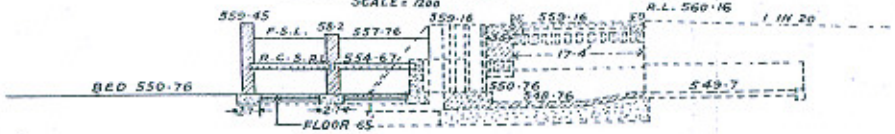
SECTION ON C.D.

SCALE = 1/200

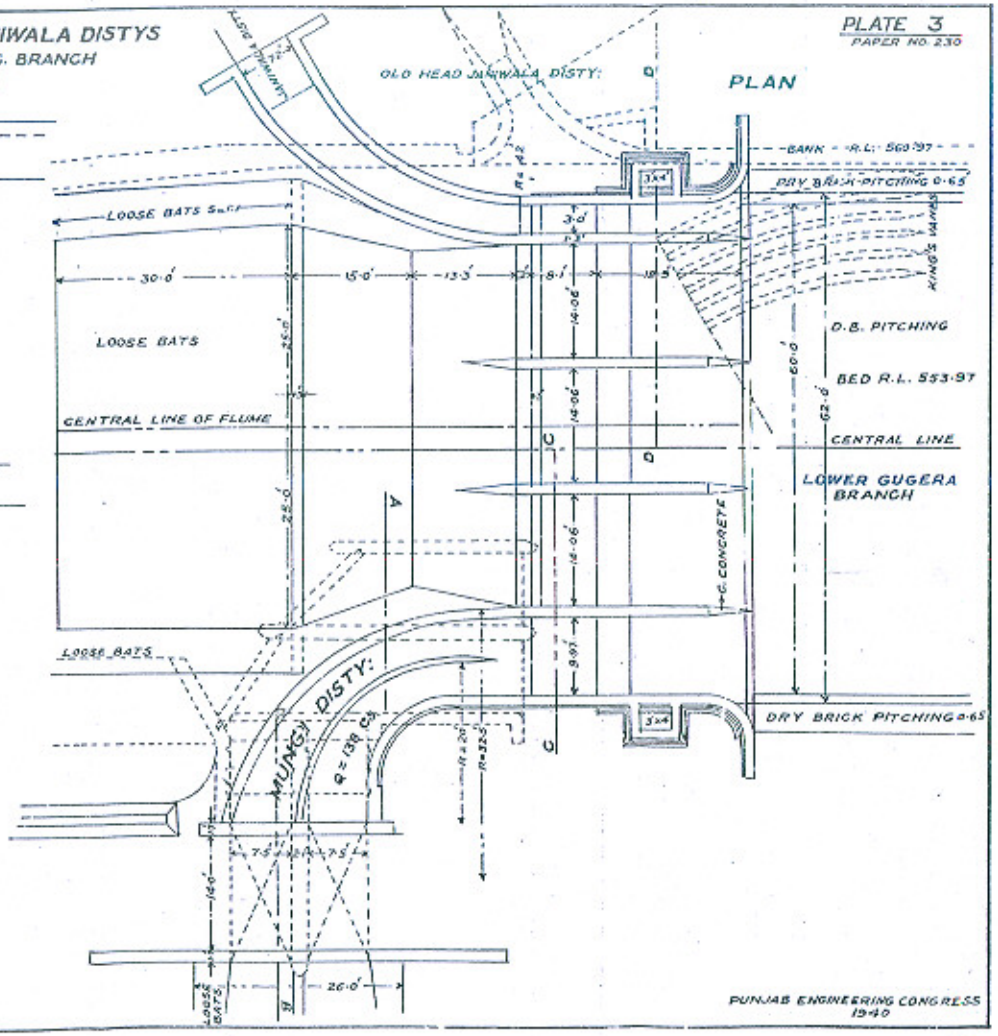


SECTION ON A.B. (SKIMMER SLAB)

SCALE = 1/200



PLAN



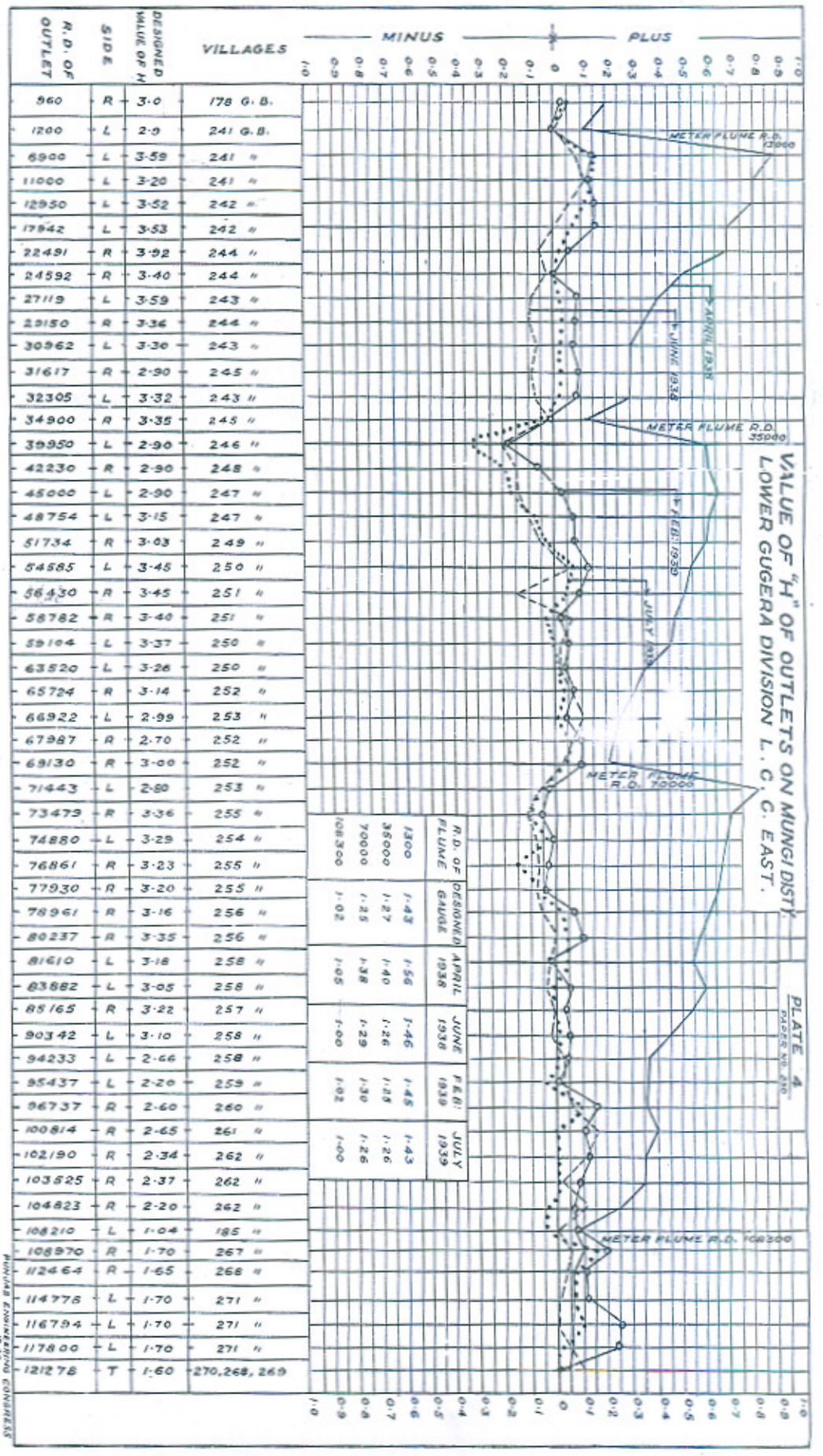
PUNJAB ENGINEERING CONGRESS 1940

VALUE OF "H" OF OUTLETS ON MUNGI DISTY. LOWER GUGERA DIVISION L. C. C. EAST.

PLATE 4
PAPER NO. 210

R.D. OF OUTLET	SIDE	DESIGNED VALUE OF H	VILLAGES
960	R	3·0	178 G.B.
1200	L	2·9	241 G.B.
6900	L	3·59	241 "
11000	L	3·20	241 "
12950	L	3·52	242 "
17942	L	3·53	242 "
22491	R	3·92	244 "
24592	R	3·40	244 "
27119	L	3·59	243 "
29150	R	3·36	244 "
30962	L	3·30	243 "
31617	R	2·90	245 "
32305	L	3·32	243 "
34900	R	3·35	245 "
39950	L	2·90	246 "
42230	R	2·90	248 "
45000	L	2·90	247 "
48754	L	3·15	247 "
51734	R	3·03	249 "
54585	L	3·45	250 "
56430	R	3·45	251 "
58782	R	3·40	251 "
59104	L	3·37	250 "
63520	L	3·26	250 "
65724	R	3·14	252 "
66922	L	2·99	253 "
67987	R	2·70	252 "
69130	R	3·00	252 "
71443	L	2·80	253 "
73479	R	3·36	255 "
74880	L	3·29	254 "
76861	R	3·23	255 "
77930	R	3·20	255 "
78961	R	3·16	256 "
80237	R	3·35	256 "
81610	L	3·18	258 "
83882	L	3·05	258 "
85165	R	3·22	257 "
90342	L	3·10	258 "
94233	L	2·66	258 "
95437	L	2·20	259 "
96737	R	2·60	260 "
100814	R	2·65	261 "
102190	R	2·34	262 "
103525	R	2·37	262 "
104823	R	2·20	262 "
108210	L	1·04	185 "
108970	R	1·70	267 "
112464	R	1·65	268 "
114776	L	1·70	271 "
116794	L	1·70	271 "
117800	L	1·70	271 "
121278	T	1·60	270,268, 269

R.D. OF FLUME	DESIGNED GAUGE	APRIL 1938	JUNE 1938	FEB: 1939	JULY 1939
1300	1·43	1·56	1·46	1·45	1·43
35000	1·27	1·40	1·26	1·25	1·26
70000	1·25	1·38	1·29	1·30	1·26
108300	1·02	1·05	1·00	1·02	1·00



PUNJAB ENGINEERING CONGRESS 1940

PLATE 5
PAPER NO. 230

LONG: SECTION OF AWAGAT DISTY:

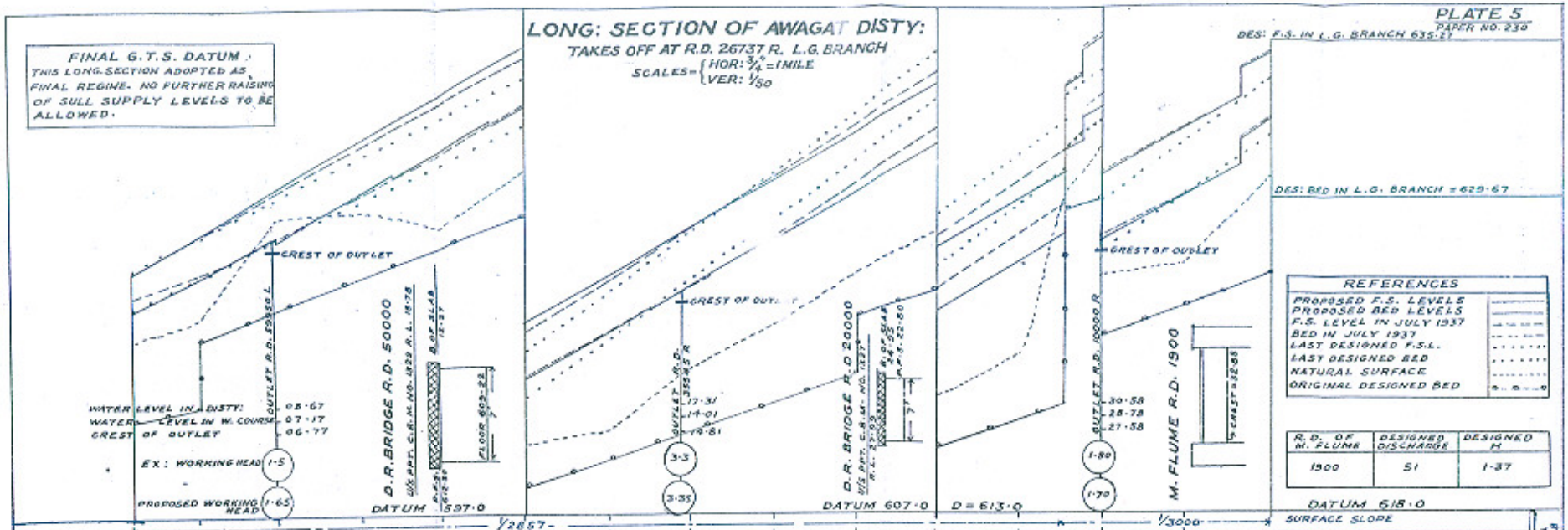
TAKES OFF AT R.D. 26737 R. L.G. BRANCH

SCALES = { HOR: 3/4 = 1 MILE ; VER: 1/50

FINAL G.T.S. DATUM :
THIS LONG-SECTION ADOPTED AS FINAL REGIME. NO FURTHER RAISING OF SULL SUPPLY LEVELS TO BE ALLOWED.

DES: F.S. IN L.G. BRANCH 635·27

DES: BED IN L.G. BRANCH = 629·67



REFERENCES

- PROPOSED F.S. LEVELS
- PROPOSED BED LEVELS
- F.S. LEVEL IN JULY 1937
- BED IN JULY 1937
- LAST DESIGNED F.S.L.
- LAST DESIGNED BED
- NATURAL SURFACE
- ORIGINAL DESIGNED BED

R.D. OF M. FLUME	DESIGNED DISCHARGE	DESIGNED H
1900	51	1·37

SURFACE SLOPE	1/2857 — 1/3000
FULL SUPPLY DISCHARGE	5 — 8 — 13·0 — 15·0 — 22 — 25 — 30 — 34 — 37+40 — 49 — 55
FULL SUPPLY DEPTH	1·4 — 1·55 — 1·8 — 2·0 — 2·1 — 2·2 — 2·25 — 2·4 in 2·45 — 2·5
BED WIDTH	3·0 — 4 — 5·0 — 5·5 — 6·5 — 7·0 — 7·5 — 8·0 — 10·5 — 11·5
PROPOSED F.S. LEVELS	608·0 — 607·1 — 607·0 — 608·6 — 607·0 — 608·6 — 607·0 — 608·6

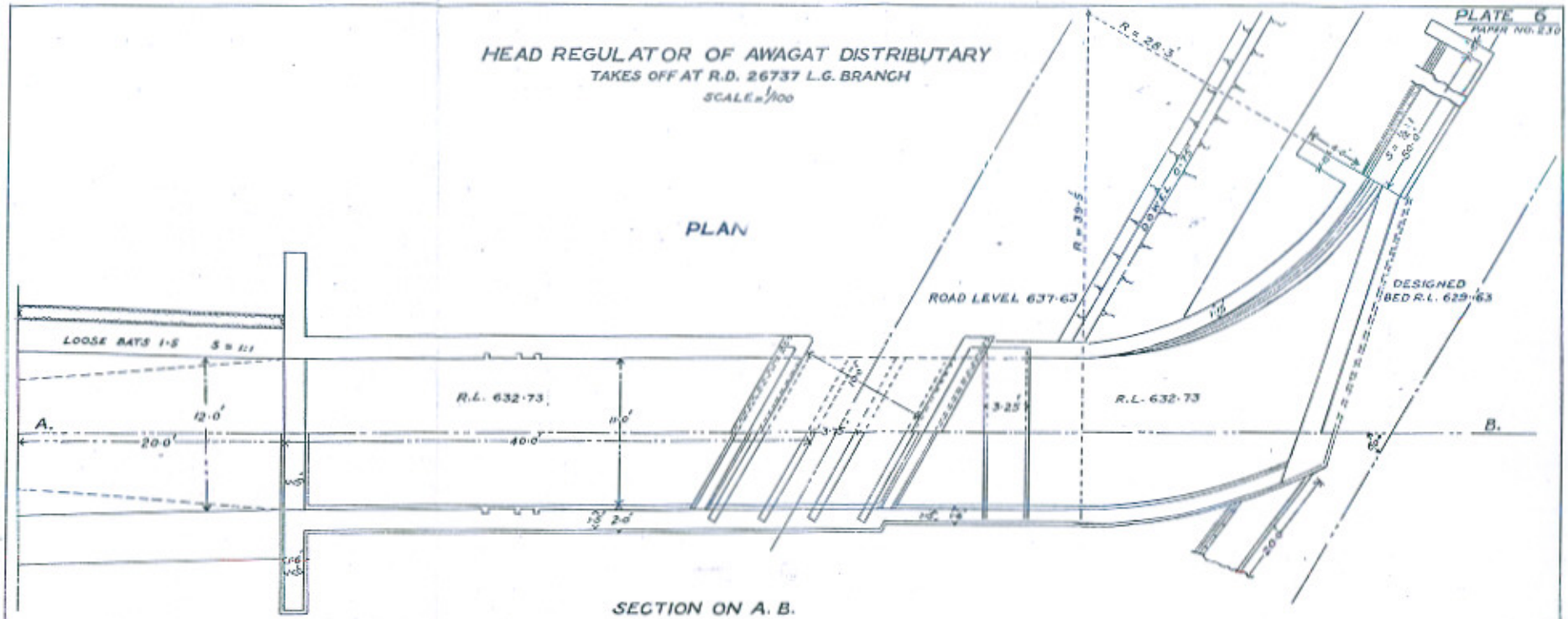
PLATE 6
PAPER NO. 230

HEAD REGULATOR OF AWAGAT DISTRIBUTARY

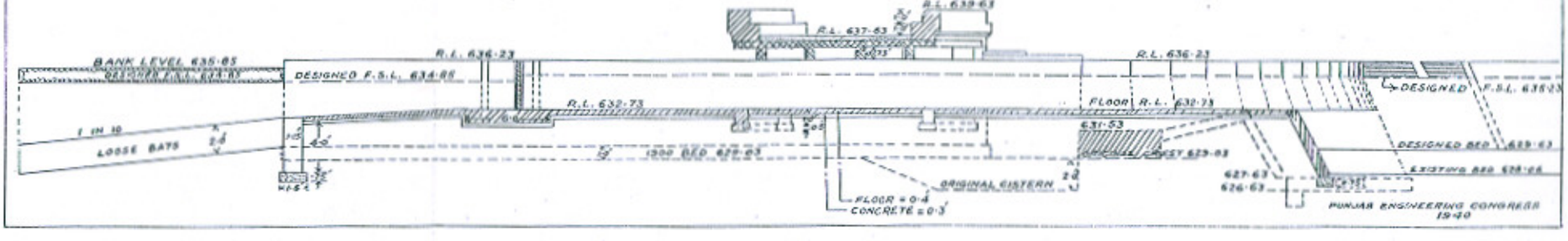
TAKES OFF AT R.D. 26737 L.G. BRANCH

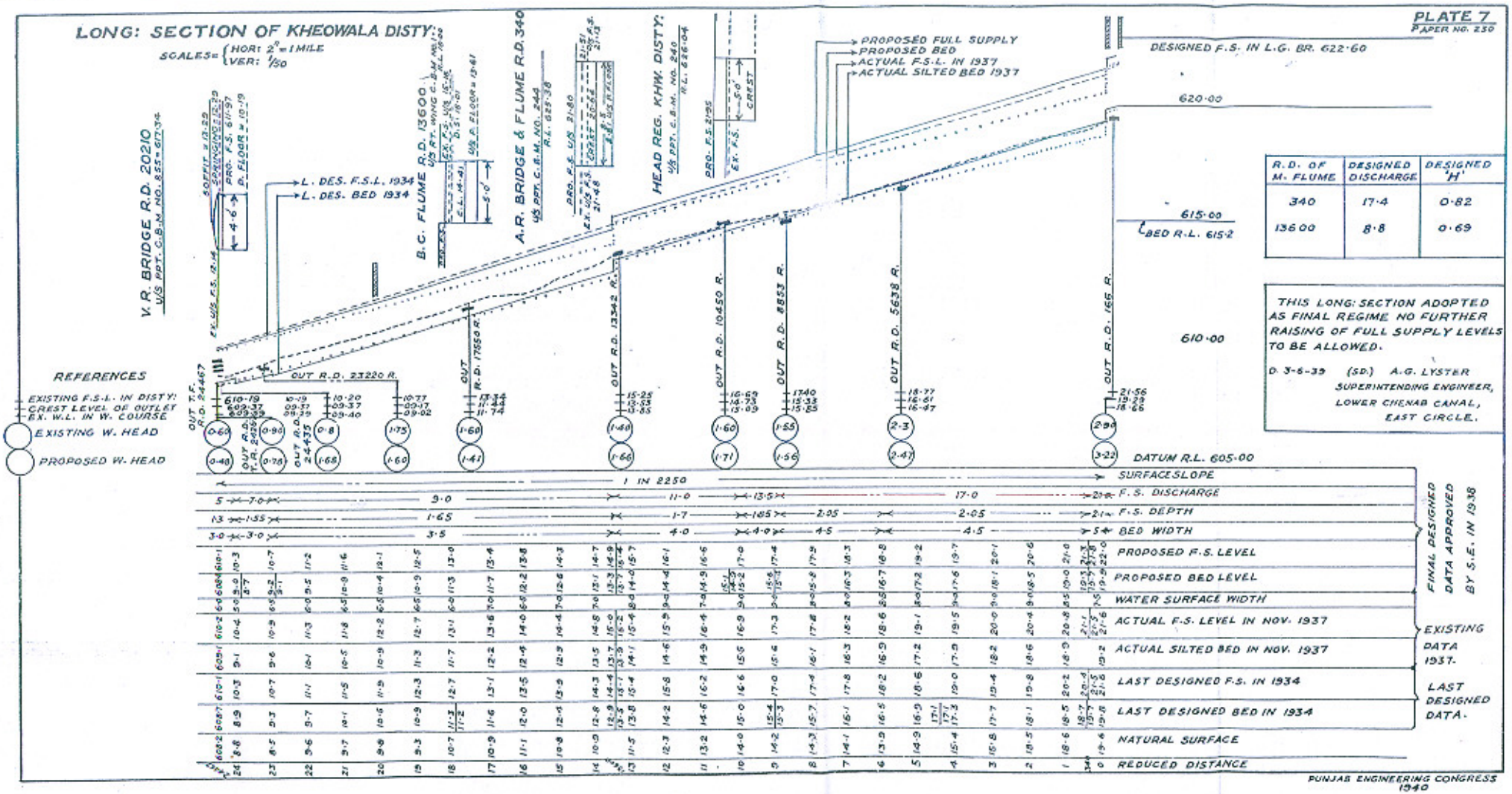
SCALE = 1/100

PLAN



SECTION ON A. B.





R.D. OF M. FLUME	DESIGNED DISCHARGE	DESIGNED 'H'
340	17·4	0·82
13600	8·8	0·69

THIS LONG: SECTION ADOPTED AS FINAL REGIME NO FURTHER RAISING OF FULL SUPPLY LEVELS TO BE ALLOWED.

D. 3-6-39 (SD.) A.G. LYSTER
SUPERINTENDING ENGINEER,
LOWER CHENAB CANAL,
EAST CIRCLE.

PUNJAB ENGINEERING CONGRESS 1940

PLATE 8
PAPER NO. 230

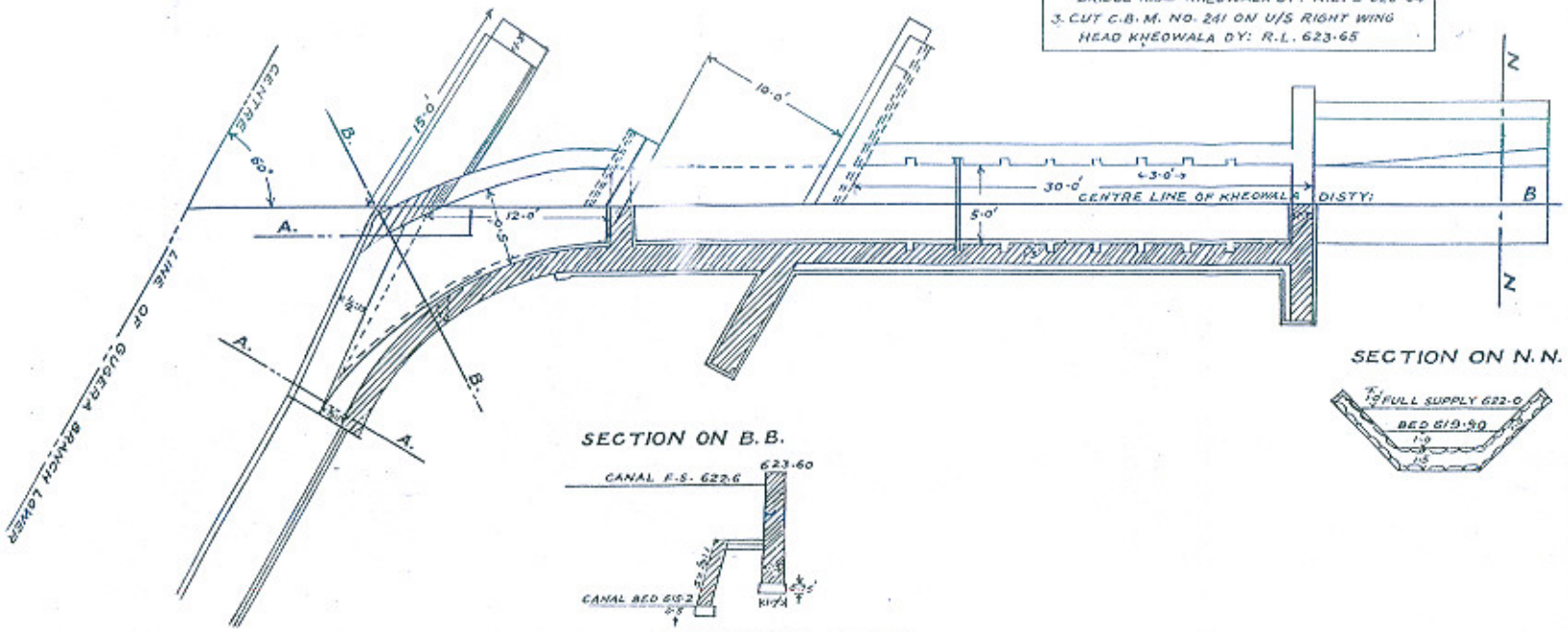
LOWER GUGERA DIVISION L.C.C.

HEAD REGULATOR OF KHEOWALA DISTY: R.D. 64700 GUGERA BRANCH LOWER

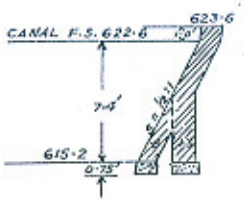
SCALE = 1/100

FINAL G.T.S. LEVELS

1. CREST R.L. = 619·39
2. CUT C.B.M NO. 240 ON U/S PARAPET BRIDGE HEAD KHEOWALA DY: R.L. = 626·04
3. CUT C.B.M. NO. 241 ON U/S RIGHT WING HEAD KHEOWALA DY: R.L. 623·65



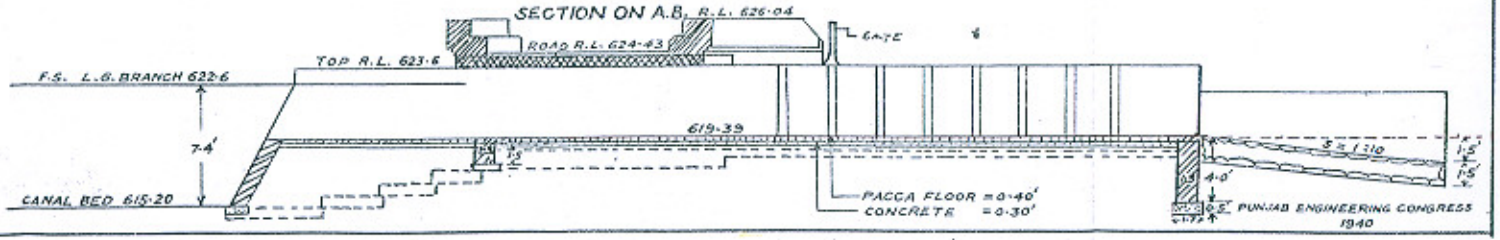
SECTION ON A.A.



SECTION ON N.N.

SECTION ON B.B.

SECTION ON A.B. R.L. 626·04

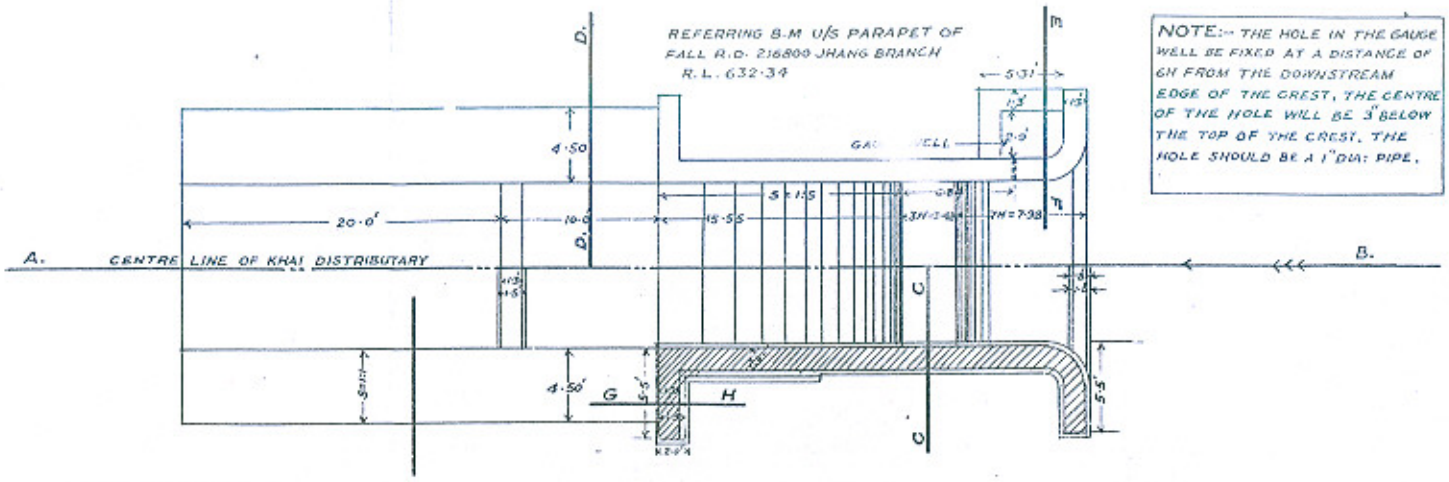


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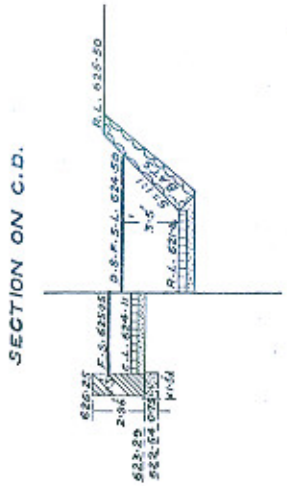
LYALLPUR DIVISION L.C.C.

PROPOSED METER FLUME AT R.D. 500 KHAI DISTRIBUTARY

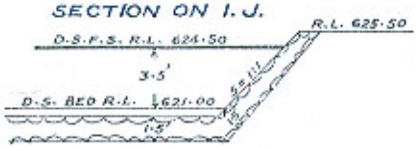
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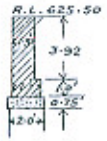
NOTE:— THE HOLE IN THE GAUGE WELL BE FIXED AT A DISTANCE OF 6N FROM THE DOWNSTREAM EDGE OF THE CREST, THE CENTRE OF THE HOLE WILL BE 3" BELOW THE TOP OF THE CREST. THE HOLE SHOULD BE A 1" DIA: PIPE.



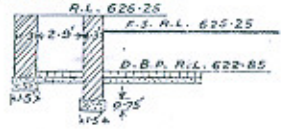
SECTION ON I.J.



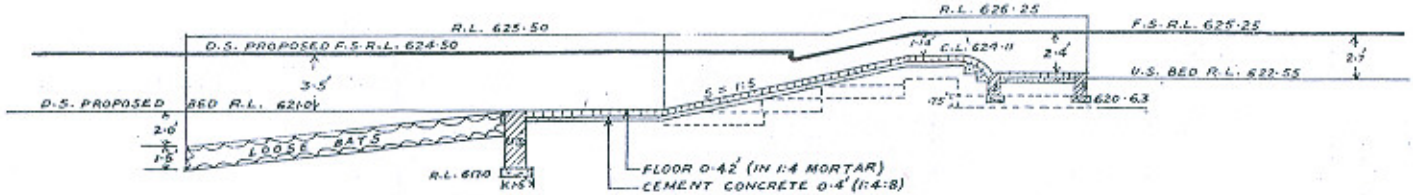
SECTION ON G.H.



SECTION ON E.F.



SECTION ON A.B.



CALCULATIONS

$Q = C \times B \times (H + h_a)^{3/2}$

$36·6 = 3·62 \times 10 \times (H + h_a)^{3/2}$

$\therefore (H + h_a)^{3/2} = 36·6 \div 30·2 = 1·276$

OR $H + h_a = 1·18$

$h_a = V\alpha^2/2g = \frac{1·5 \times 1·6}{64·4} = 0·04$

$\therefore H = 1·18 - 0·04 = 1·14$

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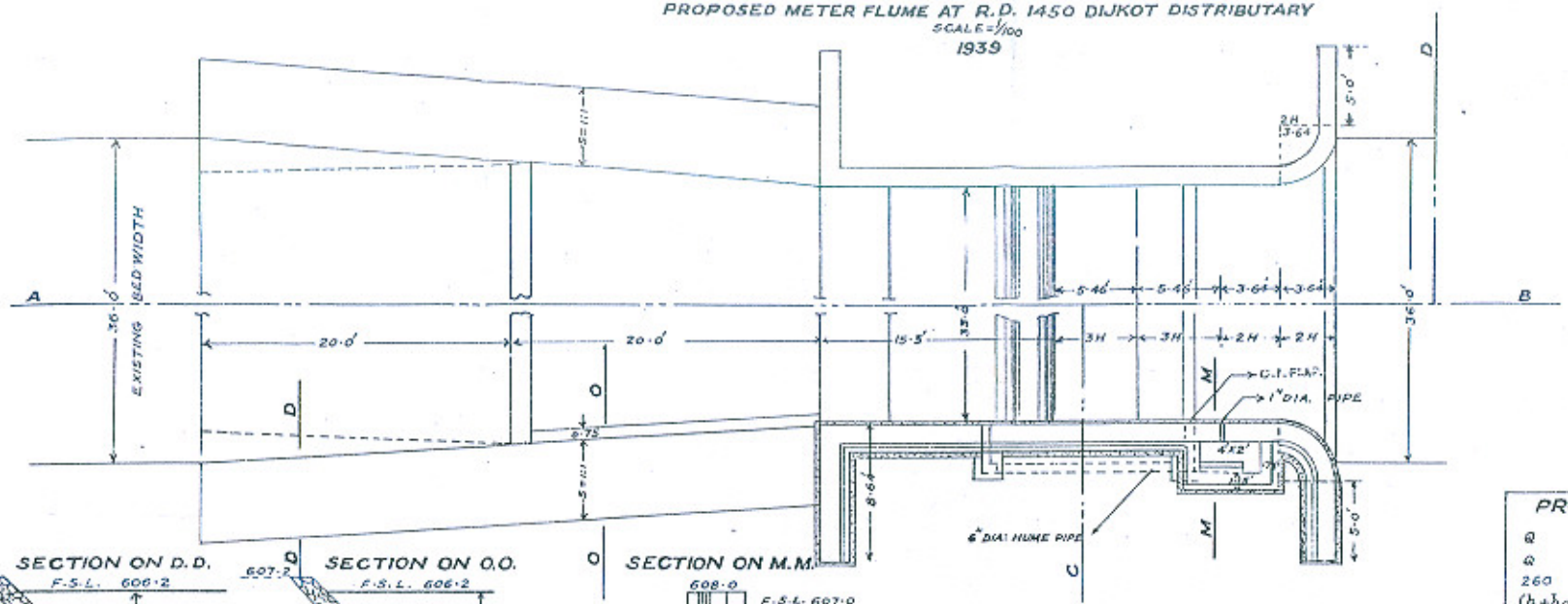
PLATE 10
PAPER NO. 259

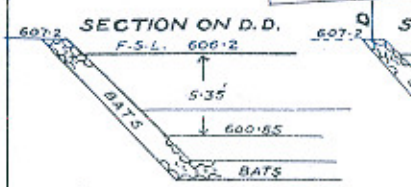
HAFIZABAD DIVISION L.C.C.

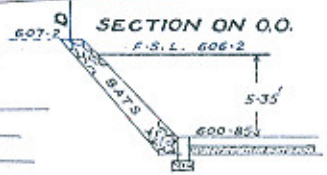
PROPOSED METER FLUME AT R.D. 1450 DIJKOT DISTRIBUTARY

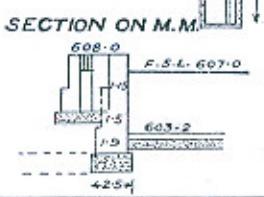
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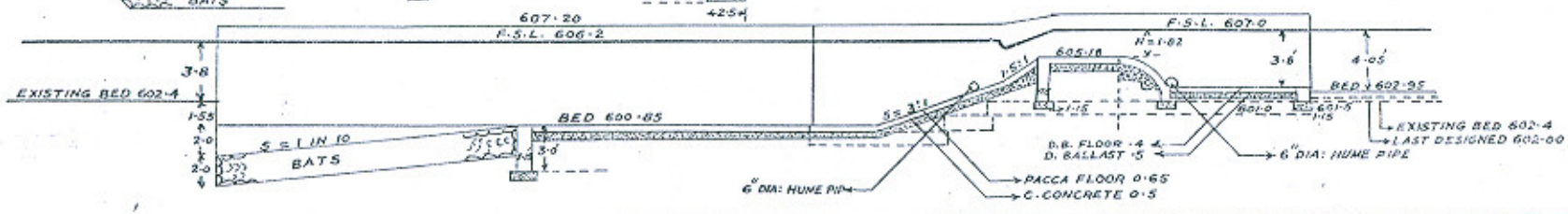
1939











PROPOSED DATA

Q	=	260 CUSECS
Q	=	$C x b x (h+ha)^{3/2}$
260	=	$3·05 \times 33 \times (h+ha)^{3/2}$
$(h+ha)$	=	1·88
ha	=	$\frac{260 \times 260}{35 \times 33 \times 3·6 \times 3·6 \times 644}$
	=	0·06
h	=	1·88 − 0·06
	=	1·82'

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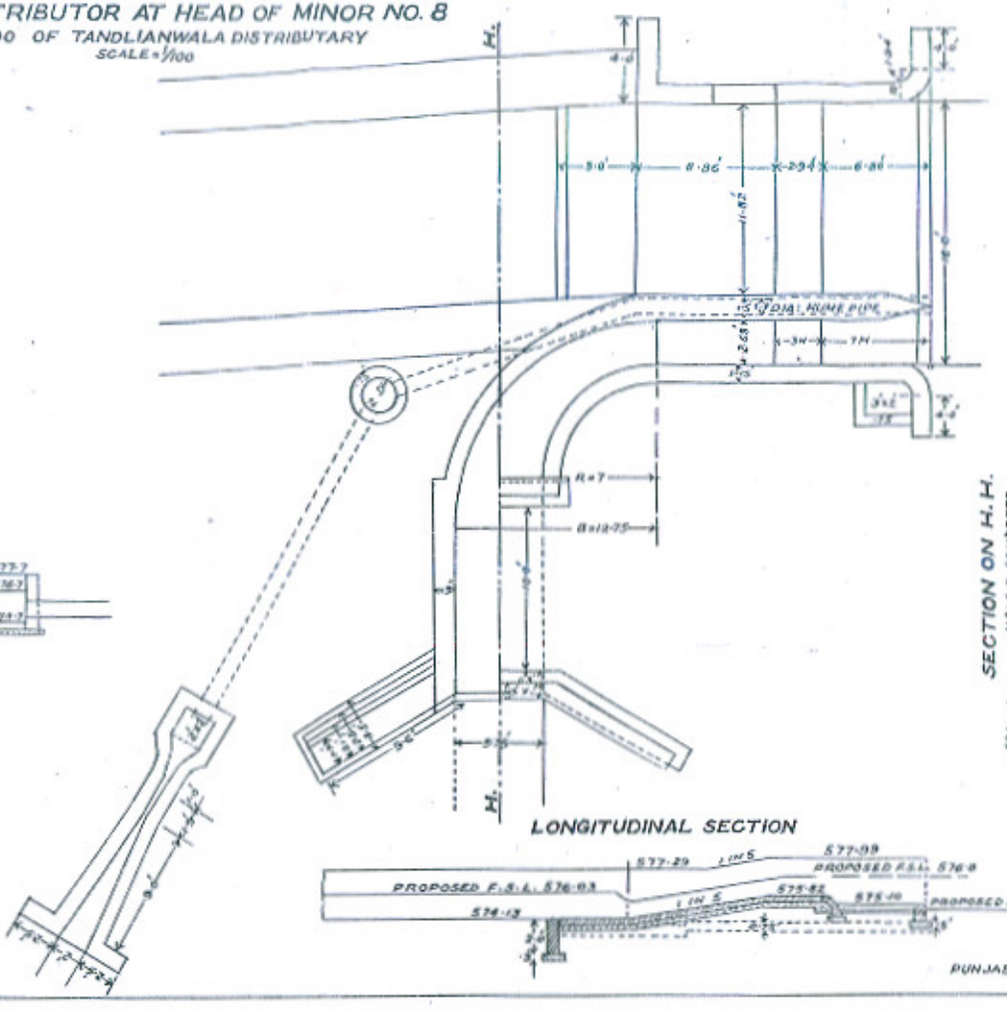
PLATE II
PAPER NO. 230

PLAN OF DISTRIBUTOR AT HEAD OF MINOR NO. 8

R.D. 9000 OF TANDLIANWALA DISTRIBUTARY

SCALE = 1/100





LONGITUDINAL SECTION



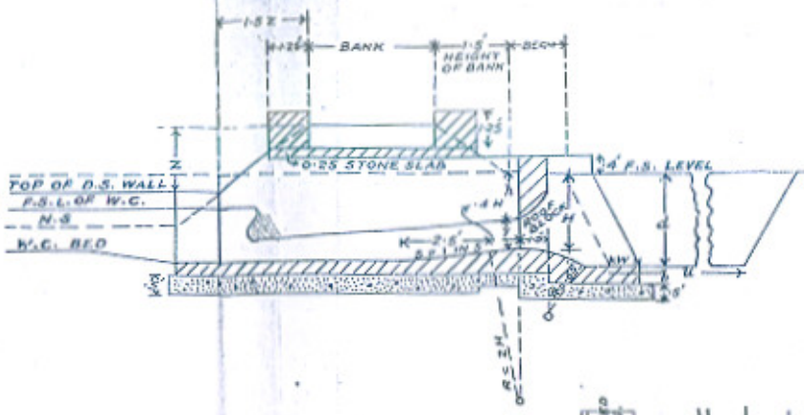
SECTION ON H. H.

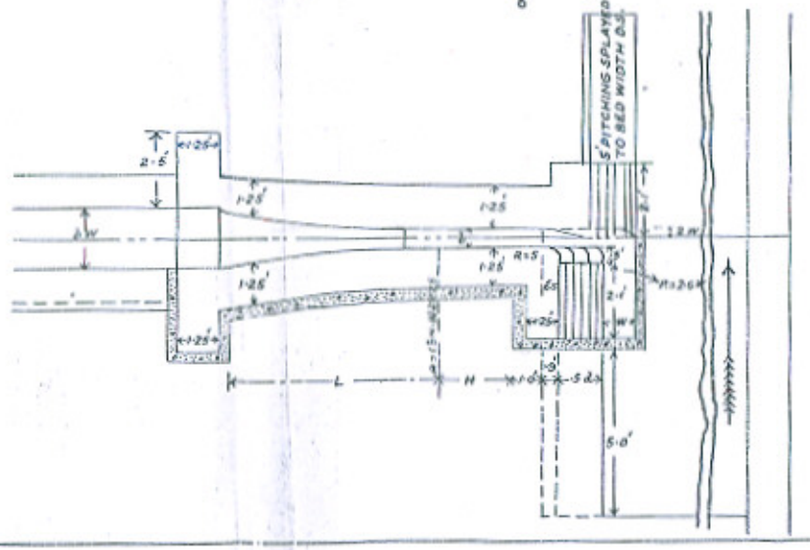
1:2:4 C. CONCRETE

PUNJAB ENGINEERING CONGRESS
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SHARMA'S MODIFIED DESIGN FOR AN A.P.M. OUTLET SET AT 0·8 d

PLATE 12
PAPER NO. 230





BED WIDTH IN CHANNEL U.S. OF OUTLET = b_u
DEPTH IN CHANNEL U.S. OF OUTLET = d
DISCHARGE IN CHANNEL U.S. OF OUTLET = Q
BED WIDTH IN CHANNEL D.S. OF OUTLET = b_d
DISCHARGE OF OUTLET = q
DEPTH OF CREST $H = 0{\cdot}8\,d$
DEPRESSION OF ROOF BLOCK = h
WIDTH OF A.P.M. = B
FOR H LESS THAN 2' $q = KB(H^{3/2} - h^{3/2})$
FOR H MORE THAN 2' $q = 1{\cdot}5\,BY\sqrt{h}$
HEIGHT OF OPENING $= H - h = Y$
MINIMUM WORKING HEAD = h_m
ACTUAL WORKING HEAD = h_w
PROPORTIONATE WIDTH OF WATERWAY FOR OUTLET DISCHARGE = $w = C\frac{q}{Q}(b_u + d/2)$
WIDTH OF APPROACH = W
SPLAY OF U.S. SIDE WALL $= S = (W - B)$
RADIUS OF SPLAY ON SIDE = S
DISTANCE OF A.P.M. BLOCK FROM CENTRAL LINE U.S. = $b_u/2 + d/2 + S$
LENGTH OF OUTLET = L
RADIUS OF OUTFALL $= (\frac{1}{2}W - B)\,2{\cdot}5\,2{\cdot}5$
RADIUS OF CURVATURE OF D.S. PROJECTED WING $= 2{\cdot}6\,W$
WIDTH OF WATER COURSE
- 0 TO 1 CUSEC = 1·5 FT
- 1 TO 2 CUSECS = 2·0 FT
- ABOVE 2 CUSECS = 2·5 FT

$C = \frac{\text{AVERAGE VELOCITY IN CHANNEL U.S.}}{\text{VELOCITY NEAR THE SIDE U.S.}}$

$C = 2{\cdot}0$ FOR HEAD REACH IN MAJOR DISTY.
$= 1{\cdot}5$ FOR MIDDLE REACH IN MAJOR DISTY.
$= 1{\cdot}25$ FOR TAIL REACH IN MAJOR DISTY.
$= 1{\cdot}0$ CHANNELS BELOW .0 CUSECS.

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DISCUSSION.

In introducing his paper Mr. Jesson said that, although he had written to several Members asking them to send him their comments on his paper as early as possible, he had received written comments from only one Member, so it might be difficult to answer some of the criticism, but he would do his best. He welcomed criticism, even if it was destructive, but he hoped that those Members, who offered destructive criticism, would also offer some constructive remarks.

He then referred to the question of small holdings, and pointed out that owing to a big increase in the population of the Punjab, some families had, due to the partition of holdings, to exist on only a few acres, so the equitable distribution of water for irrigation is becoming more important every year.

He next referred to the question of failures of remodelling carried out on the Lower Chenab Canal prior to 1934, and emphasized the necessity of examining the history of a channel, before attempting to remodel it, in order to ascertain, as far as possible, why failures had occurred in the past, and why the channel would not work satisfactorily.

He advocated the preparation of a history of every channel, which should be written up annually, as is done in the case of the history of the headworks of all Punjab canals, and as has been done in the East Circle of the Lower Chenab Canal.

Referring to technical details, the author said that, in his opinion, much remodelling done in the past had failed, as the head regulator of the channel had not been remodelled.

The author then drew the attention of Members to items 1 to 3 on pages 20 and 21 of the paper, and also to his remarks regarding longitudinal sections on page 31. He laid great stress on the necessity of obtaining an accurate longitudinal section of a channel, representing existing and designed conditions, before any attempt was made to remodel it. On this longitudinal section details such as crest level of outlets; water level in watercourses; working head of outlets, etc., should be shown in addition to the details usually given. A specimen longitudinal section was shown to Members.

Coming to the question of type designs for masonry works, the author advocated the provision of a broad-crested meter flume, with the width of the crest equal to

the full designed bed width of the channel, at the head of every channel taking off a main branch or canal, so as to keep a check on the discharge entering a channel, and do away with the necessity of observing monthly discharges.

In connection with the design of head regulators of distributaries, the author suggested that the Research Department should carry out experiments to ascertain the best design, and its silt drawing capacity.

The author then drew special attention to the tabular statement on page 39 of his paper, in which the percentage increase in discharge of an A. P. M. outlet for a rise of 0·3 ft. in the water level in the distributary, is given, and pointed out the necessity of setting outlets as low as possible, not only to make them draw off their fair share of silt, but also to make them as rigid as possible.

In conclusion, the author stressed the necessity of maintaining special registers, in which the value of "H", and the working head of each outlet should be recorded every month.

Mr. **A. St. G. Lyster** stated that he was in charge of the Lower Gugera Division in 1932, and the condition of the distributaries offtaking from the Lower Gugera Branch at that time was even worse than described by Mr. Jesson. They all or nearly all had the undershot gate type of head regulator placed as close as possible to the parent channels. They were all drawing heavy silt charges. They had steep slopes in the head reaches and flat slopes in the lower reaches whereas according to Lacey's diagrams the slope should be steeper for smaller discharges. They all had wide shallow sections. The only palliatives then being applied were raising and strengthening banks, raising bridges of which the majority were in a drowned condition and spur bushing. Spur bushing which was tried out lavishly on Pauliani and Awagat distributaries produced no real berm growth and so was a waste of money.

The shortage at the tail of Mungi was so bad that it was a miserable experience going on tour there.

The speaker regretted to relate that very little improvement was effected in his time, and it was a revelation to him to return to the Lower Chenab Canal, East Circle, in 1938 and to see the improvements.

There was not the least doubt that the failure for so many years to get these channels working well was due

to the fact that the problem was not viewed as a whole and though it was realised by one officer or another that the greatest fault lay in the design of the head regulators, makeshift remedies such as advanced raised crests and "King's vanes" were applied and no new design was introduced.

With the above history before us it was impossible not to approve Mr. Jesson's conclusion that there should be central control of remodelling. The only alternative was to retain the same Superintending Engineer in one Circle until the remodelling was completed say 3 to 4 years. Usually it was not possible to arrange this. The speaker added that neither the Superintending Engineer nor the remodelling control office, whichever was functioning, should consider any proposal of which the report did not consider the recent history of the channel and discuss its whole condition and gave reasons for making alterations in one feature only.

Mr **Lyster** emphasized the importance of maintaining the correct section of a distributary. He considered that this duty was commonly overlooked in maintenance work and that few Sub-Divisional Officers or Subordinates went down a distributary during closure and checked the existing bed width against the designed.

As regards the distribution and control points designed by Mr. Jesson, there was much to be said for designing all these weirs with width equal to bed width of channel. This made for uniformity of co-efficient as the degree of end contraction of the jet was much the same in different structures. The action downstream was well distributed and the worst fault they had was that the high crest held up the "nikal" water in the distributary when it was closed down and robbed the tail outlets of this perquisite.

As regards the distributor shown in Plate 3, the distribution of silt in this masonry work was commented on in detail in the Report for the year 1938 of the Punjab Irrigation Research Institute The speaker quoted from the conclusions given in that report.

1. The bays of the offtakes took less coarse silt than the bays for the main channel.

2. The main channel bay nearer the smaller offtakes took less coarse silt than that nearer the larger offtakes.

3. The offtakes generally did not take any increased share of a marked rise in the silt content of the parent channel.

4. The distribution of silt of such works was different at different sites in the same channel.

Conclusions 1 to 3 applied to the individual distributor shown in Plate 3.

5. Roughly each cft. of water in the Lower Gugera Branch carried 1 oz. of fine silt; ⅛ oz. of medium silt and 1/10—1/20 ozs. of coarse silt.

With discharge equal to 500 cusecs, the daily quantities of silt came to 27000 cft. fine, 9000 cft. medium and about 2000 cft. coarse silt.

K.B. Sh. **Minhaj-ud-Din** said that there were three factors which between them kept the silt conditions on a channel in equilibrium. These were :—

(*a* The design of the head regulator.

(*b*) The design of the channel.

(*c*) The design of the outlets.

Under paragraph "Exclusion of coarse silt from distributaries". Mr. Jesson had sounded a note of caution against excessive silt exclusion from distributary heads. This was very important; otherwise there would be troubes in the parent channel and its tail distributaries. It seems to the speaker that silt exclusion from heads of distributaries taking off from the Northern Branch of the Lower Jhelum Canal had been overdone, as there was more silt at the tail of the branch now than there was 8 years ago. As a general principle, therefore, every distributary should be made to draw off the maximum amount of coarse silt which it could stand. A distributary on which steeper gradients were available could reasonably be given more than its proportionate share of silt and similarly a distributary, where conditions were less favourable, should be given less.

The design given in Plates 3 and 11 allowed the offtaking channels to draw a quantity of silt proportionate to the discharge. The line of offtake was parallel to the centre line of the parent channel and both the offtake and the parent channel passed over broad crested weirs, whose B was proportionate to their discharges. The design was for the first time published in the *Indian Engineering*, dated 26th January 1929, and was based on a number of silt experiments carried out by the undersigned in the years 1927-28, also reported in the same issue of that paper. The design had since been extensively used on the Upper Jhelum Canal, the Lower Jhelum Canal and the

Lower Chenab Canal. This design was very suitable where a proportionate distribution of silt was desirable.

In old days we had pipe outlets, which were usually below bed level and took off from the distributary large quantities of silt. These outlets with their high silt-draw and the periodical silt clearances of minor distributaries kept things going. Our latest type of outlet was the A.P.M. This was as good as the old pipe outlet, if it were placed at or below bed level. But such setting was not often possible for want of the necessary amount of working head, the A.P.M. was placed above bed level or else it was substituted by what was known as the Open Flume Outlet. The latter was a bad silt-drawer, as also the A.P.M. if placed above bed level. A warning was needed against the use of these two types. The only proper place for the Open Flume was the tail cluster. As regards an A.P.M. above bed level, there was a good substitute for it in undersigned's BEND-OUTLET which, like an A.P.M. was a semi-module and as a silt-drawer was as good as an A.P.M. at or below level. (For details of this outlet, see *Indian Engineering*, dated 13th February, 1926). Mr. Jesson had used this type of outlet on the Salam Distributary of the Lower Jhelum Canal with satisfactory results.

In his paper he mentioned reach R.D. 67,000 to 125,000 of the Mithalak Distributary, where the gradient was 1 : 5714 and which silted. The speaker found that on this Distributary upstream of 125,000, there were as many as 29 outlets with working heads varying from 2 to 4·0 ft. The above reach could probably be completely cured if fullest advantage was taken of these high working heads and the A.P.Ms. were placed below bed level, which was possible to do with the working heads available. The speaker had noticed during his inspections that the watercourses had no silt heaps on them, which meant that they were capable of disposing of more silt. A number of A.P.Ms. on the Distributary were also above bed level, which could not be taken down to bed level for want of sufficient working heads. These could be replaced by Bend-Outlets mentioned above, which, with the available working heads, would draw as much silt as an A.P.M. at or below bed level.

The position of the hole in the gauge well upstream of the crest in meter flumes was in the opinion of the speaker not correct. The hole should be in the upstream face of the wing wall at a distance of 10-h from the downstream

edge of crest. The reason was that by the time the stream reaches the line of 6-h the water level had fallen very considerably.

Another point of some importance was that the greater the B of a broad-crested weir the less the action downstream. The width of a control point might, therefore, with advantage, be made somewhat larger than the downstream bed width of the channel. It had better be made equal to the downstream bed-width plus the full supply depth. This would give a larger cistern for dissipation of energy between the crest of the flume and the downstream earthen channel.

Longitudinal staking and bushing, as suggested by Mr. Jesson was the best and quickest way of forming berms. Other methods were not quick and the results were uncertain.

In his formulæ Mr. Jesson has ignored embankment of channels above ground level. The speaker suggested a modification in his formulæ as follows :—

$$\text{Bank width} = f + d + \sqrt{\frac{b}{d}}$$

$$\text{Berm width} = f + c + \frac{d}{2}$$

where f was the height of bed above ground level and c the constants as given by Mr. Jesson on page 23 of his paper.

A study of graphs such as the one shown in plate 4, was very useful. The speaker suggested that these graphs should be prepared by the Sub-Divisional Officers and sent up along with the yearly Efficiency Diagrams of outlets of channels.

Maintenance of Registers showing 'H' and the working head of outlets each month should, the speaker thought, be prescribed for all Divisions.

Reporting of tail gauges by Sub-Divisional Officers, Zilladars and Overseers direct to the Executive Engineer, whenever they happen to inspect a tail, was a very good tip for the Executive Engineers.

Mr. Jesson had suggested a policy for remodelling and remarked that abolition of remodelling of outlets would make Government, and the Irrigation Branch in particular, more popular. This must not be taken to mean that the Irrigation Branch did not have this ideal in view so far. It had always been before them. Indeed every Executive Engineer and his Superintending Engineer, who

remodelled a channel thought that they had put the last brick on the edifice. The difficulty was that remodelling of channels was a highly specialized work and could not be tackled by officers who did not have considerable previous experience of it. Where the local officers did not possess the necessary experience, they made a mess of the whole thing. The speaker entirely endorsed Mr. Jesson's suggestion that a limited amount of central control of remodelling was now necessary. He suggested that the work might suitably be entrusted to the Central Designs Office, who would accumulate experience and be in a position to advise on all remodelling schemes before they were carried out at site.

Mr. **B. L. Uppal** said that the author had taken pains to review the history of four channels finally remodelled under his charge of superintendence. The speaker agreed that defects in distribution of water and unsatisfactory working of channels were due to the following causes :—

(*a*) Defective head regulator,

(*b*) Channel being wide and shallow.

(*c*) Incorrect setting of out-lets.

The original design of a distributary head regulator consisted in keeping the floor of the regulator at the bed level of the parent channel, and fitting it with a movable gate. Generally, the face of the regulator was kept parallel to the channel, such that the offtaking channel was normal to the parent channel, even if it was a ditch channel. It had since been realized, that if at a bifurcation one channel was straight, *i.e.*, in continuation of the parent channel, and the other at right angles to it, the latter would get heavier share of silt than the former. Our distributors or regulators should not only be capable of taking proportional supplies, but they should have proportional share of silt load. The defect was rectified if the flume regulators of the offtaking channels were so placed that they had more or less the same line of approach from the parent channel. For new designs, the offtake should be skew, so that the offtaking channel may get the advantage of the velocity of approach in the parent channel.

Another essential feature was that at every open offtake from a parent channel, the sections of the parent channel upstream and downstream of the offtake must be correct, *i e.*, proportional to the discharges. This was very necessary where there was an appreciable drop in the discharges.

Having secured a defectless regulator, it is very necessary to see that the channel was designed with correct sections and that the designed sections were maintained at site. To maintain a channel in good order, it was necessary to see that it did not fall out of proper sections. To control F. S., levels as designed, it was essential that the bed levels should be controlled, and to ensure correct bed levels, it was essential that widths of the channel should be controlled. Thus, not only were control points necessary at every fall and below every large offtake, but all the masonry works should have correct water-way, and correct floor level. If the water-way of a masonry work was larger than the normal width required for the channel at the site, the silted bed will be higher than the designed bed level which will upset the W. S. slope and the designed H over the crest of the out-lets in the reach above such a masonry work.

Taking the case of Mungi Distributary remodelled by the author, it might be observed that the Engineers-in-charge had been meddling with it ever since 1900. Inspite of persistent trials, they failed to find out the defects and to treat them successfully till 1938. Even the author took four years to find out workable design for the distributary. Each trial or operation was given the name of remodelling. It was on account of such unsuccessful re-modelling that the Department had got a bad name and the people were afraid of such re-modellings. Recently such re-modellings had given birth to agitation—the Zamindars closing their out-lets and refusing to take water. Such an agitation had its origin, the speaker believed, in the East Circle of Lower Chenab Canal, and it spread to the other Circles as well.

In the re-modelled design of the regulator (Plate No. 3) the crest had been raised to R. L. 556.27 which was 2 3 ft. above the revised bed level of the parent channel. No calculations were given. The cross-sections show needles on the crest. This signified that the widths of flumes for the offtaking and parent channels were not proportional to the F. S. discharges. Under F. S. conditions, no regulation should be necessary.

The old skimmer platform did not work, because the parent channel downstream was wide and shallow. Widening of the bridges was probably a mistake. No data was given to see how far this widening was justified. Tight bridges could, with advantage, be flumed, and such headless flumes would provide further control points to control bed and F. S. levels.

The rise of bed levels as shown on plate No. 5 was remarkable. It would be apparent that either the original design was very wrong, or there was a big difference in the values of the Bench Marks for the old and the new surveys.

Looking at the design of the head regulator (Plate No. 6), it would be seen that the crest was over 60 ft. long. No calculations were given, but it appeared that the flume width was calculated to work as a headless flume. The crest was 4.67′ above the existing bed level of the parent channel, and the value of min. H over the crest was 2.1. It would be evident that when, the parent channel was in low supply. the distributary would not be able to get its F. S. discharge. The longitudinal section (Plate No. 5) showed that the construction of a meter flume at R. D. 1900 was apparently a mistake, as thereby the working head of the distributary had been reduced. Further the two outlets at R. D. 10,000 showed that they had working head of over 1·7′. Thus the head reach of the distributary could be easily lowered by 2 ft.

It would also be noticed from Plate No. 6, that the normal sections of the parent channel required upstream. and downstream of the offtake had not been considered.

It would be noticed from page 17 and Appendix A that sections of the distributary at its head were designed as below: —

	Q.	B.	F. S. Depth.	W. P.
1900	28	5·0	3·0	8·8
1903	25	13·0	1·5	16·4
1904	25	5·0	2·7	11·0
1938	20	5·0	2·1	9·6

The normal section for a discharge of 25 cusecs should have a W. P. of about 12·5′. This shows how badly the sections were taken in the old designs.

It was stated by the author that the old head regulator, being defective, was scrapped, and that a new work was constructed in 1933 or 1934. Looking at the new design (Plate No. 8), one would find that a raised crest 4·19′ above the canal bed had been provided. The distributary would fail to get its authorised discharge as soon as the F. S. L. in the parent channel falls below R. L. 622·0.

The control point introduced at R. D. 13,600 has a fall of 0·5′. The working heads of all the outlets above this control point were over 1·66′. Thus by the removal of this control point, and the meter at head, a working head of more than a foot from the parent channel could be secured.

A meter flume just below the head regulator should be provided where the working head from the parent channel into the distributary is ample, otherwise the distibutary would suffer when the parent channel was in low supply. Where a regulator existed in the parent channel, it would be advisable that the F. S. L. in the parent channel should be fixed, and the head flume of the distributary designed to give its A. F. S. discharge with that fixed F. S. L. In such cases, the necessity for a meter-flume in the head reach vanishes, and gate regulation at the head of the distributary with the attached evil of interference by the gauge reader could be avoided.

The author of the paper had stated that the method adopted in the past for preparing longitudinal sections had been unsatisfactory. It was not possible to show all the data on the L. Section. Whereas, hydraulic survey of a channel showing N. S. bed levels, F. S. levels and bank levels could best be plotted on a longitudinal section, it was not conveniently possible to show full data about the existing and the proposed outlets. For that propose, a design-form with headings as shown on the attached form would be extremely useful. The design-form would show for each outlet its C. C. A., permissible area and permissible discharge, the existing and the proposed W. S. levels, the discharge of the parent channel and normal sections required by reaches, the working heads and the existing and the proposed sizes of outlets. On the design form could also be shown the data about the head regulator, all the flumes or falls and all the masonry works.

Mr. **T. A. W. Foy** said that to one accustomed to the relatively flatter slopes of the Sirhind Canal and in even more marked degree of the Bikaner Canal, the most striking fact brought out by Mr. Jesson's valuable paper was that steep slopes were required on the Lower Jhelum and Lower Chenab Canals if channels were to have any semblance of regime. For example, on the Bikaner Canal the regime slope of a channel of 100 cusecs capacity was 1/6666 against 1/4000 of the Mittalak (158 cusecs) before remodelling and 1/4444 after remodelling and approximately the same conditions applied to the L. C. C. channels described.

Apart from the local evils of the defective distributary heads, this points to the comparative failure of the silt exclusion measures adopted at the Canal Heads and it would appear that much more work was required here before satisfactory conditions could obtain on the distributaries.

A secondary cause might be that for instance on the Lower Chenab the distributaries had a coarse grade of silt corresponding to the pre-silt excluder days at Khanki. Now, however, much silt might be excluded at Khanki, the coarse silt still remained in the distributary and required the steep slopes referred to for regime conditions. This argument would also apply to a distributary with a defective head even after the head was improved. If, therefore, it was desired to flatten the slope of such a channel for introducing an addition control point or for any other reason, it was essential to excavate the bed silt to one foot deeper than ultimate final bed in order to get over this difficulty.

Mr. **S. L. Malhotra** said that the author was to be congratulated on having brought out a detailed paper on a subject of vital importance for the irrigation engineers. By discussing the behaviour of some of the Distributaries of colony canals from the very start, he had given the history of the development of science of equitable distribution of water. The original head-regulators and outlets were certainly defective and had therefore given place to the modern works. It however appeared that the author had not been able to arrive at any finality in remodelling. On the Mithalak Distributary a certain length had been left to be silt cleared annually. This was certainly no solution to the problem of equitable distribution.

The author had said that in the past insufficient attention had been paid to locate and remedy hydraulic defects in channels. A persual of the paper showed that the author instead of removing defects was advocating wholesale changes in existing hydraulic data of the channel under remodelling. It was an admitted fact that left to itself a channel would acquire regime data depending on the silt contents entering at head and in various reaches of its length. The data in remodelling should agree fairly closely with this data if the channel was expected to work to designed conditions. The author's method appeared to consist of fixing a certain C. V. R. and then attempting to force the channel to adopt designed data by extensive bushing and staking. This violation of the channel sanctity was bound to fail. The best method according to the speaker was to design the channel in conformity with its existing sections and slopes. The silt contents of a main canal should, as far as possible, be distributed equally in its offtakes giving a little excess to offtakes with higher command. The outlets should, in turn, be made to take their share. Having

ensured proper disposal of silt, the channel was bound to work successfully.

The system advocated by the author was not much different from that advocated by Mr. Routh except in the use of Sharma outlets. Relaxing the rigidity of Mr. Routh in a fixed value of C. V. R. and the higher crests of outlets, the speaker was of the opinion that nothing more was needed to arrive at final data for channels. Mr. Jesson's and in fact every system of remodelling channels consisted in constructing silt-selective head regulators, introducing proper control points and outlets with low settings. All these arrangements arrived at proper silt distribution and tended to successful running of channels.

Taking the Mithalak Distributary, it could be questioned why was drastic tightening resorted to and the same procedure appeared to have been followed by the author in the East Circle. The design should have conformed as closely as possible to existing data. The author had given no reasons for preferring longitudinal bushing over Cross-Spurs. These had been tried with a marvellous success on the Shujabad Branch, where beautiful berms were developed in less than a fortnight

The author admitted that Sharma's outlets did not give correct discharges with Values of H exceeding 2·0 ft. It could be questioned as to why were these outlets used when even the co-efficients and discharges had not been accurately determined. The speaker had not seen any of Sharma's outlets working but they had not been introduced so far as he knew on any other canal probably due to their complicated structure with no advantage over existing types. The use of this type of untried outlets on Mungi Distributary by the author resulted in successive tinkering with outlets which must have upset the cultivators. The author had given useful hints for remodelling, which would prove helpful to irrigation engineers. Referring to hint No. 17, however, it would be seen that even after resorting to such a detailed and drastic system of remodelling imdadi shoots might have to be given. This practice could never be advocated by any engineer-in-charge of a channel and must never be thought of. The desired distribution should result immediately after remodelling which must otherwise be considered defective.

Two parties were mainly concerned in remodelling, *viz.* Government who provided money and the cultivators whose outlets were effected and the remodelling could be considered satisfactory if interests of both parties were

safeguarded. The remodelling should, therefore, have the qualities of being least expensive and least aggressive. The author should judge the usefulness of his remodelling from these two points of view. In this connection it would not be out of place to mention the reception the remodelling on the Haveli Project had received from the zamindars. Appreciations of the methods followed and the satisfactory distribution attained had been many and the cost had also been minimum possible.

Mr. **Radha Krishna Khanna** remarked that he had read with great interest the epic story of remodelling of channels on the Lower Jhelum and Lower Chenab Canals, which Mr. Jesson has recounted in the paper, not only on account of the great importance to irrigation engineers of the subject under discussion but also because of the unique experience of the writer of the paper. Mr. Jesson was engaged in intensive remodelling operations for nearly eleven years; and in his own words, during a considerable portion of this period, he carried out all the remodelling that could be done during the available closures of the canals. Fortunately, there was no dearth of money on the Lower Chenab Canal, as there generally was on other canals; so the available periods of canal closures being the only limitation to his work, Mr. Jesson had enormous scope for trying his maxim "if at first you don't succeed try, try, try again". Mr. Jesson did not spare himself or men, money and materials to go ahead with whatever remodelling he could do: so much so that even if a channel was taking 65 cusecs instead of 63 cusecs authorised discharge, Mr. Jesson did not hesitate to submit that channel to his usual course of five years' remodelling including of course the building of a new head regulator, constructing new outlets and replacing those outlets by Sharma type ot outlets later on.

Mithalak Distributary was opened for irrigation in 1901. Its designed slopes were 1/5000 or flatter, and in order to command high lands 30 stop dams were sanctioned or on the average say one stop dam per mile; so the actual slopes on account of the existence of stop dams must have been very much flatter than 1 5000, and yet the distributary continued to run from 1901 to 1907. The serious shortage at the tail could only be rightly ascribed to defective head regulator, and excessive draw offs at various points on account of the stop dams. There could be no question of flat slopes being responsible for the silting trouble, because the Lower Jhelum Canal itself does not draw coarse silt at its head, and the distributary takes off at a distance of 52

miles from the head of the canal, where the bed silt of the canal was very fine indeed. Between 1908 and 1914 if Mr. Woods had simply remodelled the head regulator to a flume type one, I am sure all subsequent trouble and expense would have been avoided. In support of this statement, I shall give examples of very troublesome silting channels which were treated in this manner by me several years ago, and are now working satifactorily. Between 1918 and 1928 again practically nothing was done to the channel, and we may be sure that the tail was not dry for all these years. When Mr. Jesson examined the detailed survey of the channel in 1928, he came to certain conclusions. The speaker agreed with him that the trouble was mainly due to defective head regulator, which should have been set right, necessary control points provided and the channel artificially tightened. Had this been done, the trouble would have certainly disappeared. But instead of that, most of the year 1929 was spent in getting the channel into order by immense silt clearances, etc., at enormous expense. When in 1930 the silt which was cleared in 1929 was again deposited, large sums of money were spent in getting the channel into order. But still the silt trouble on this channel continued which in Mr. Jesson's opinion it was impossible to prevent, because the slope of 1/5714 was too flat for the discharge of 60 cusecs. So before leaving the Lower Jhelum Canal in 1933, Mr. Jesson issued definite orders that the silting reach should be cleared whenever necessary.

The surface slope in the head reaches of the distributary from 0 to 67,000 was 1/4444, and in the next lower reach up to 125,564 it was 1/5714. The speaker ventured to suggest that the order of the slopes should have been the other way about, flatter in the head reach, and progressively steeper lower down, and then the trouble of poor command of which Mr. Jesson spoke would have been avoided, and also would have eliminated the necessity of his orders about frequent silt clearances. But this suggestion he had made out of regard for the susceptibilities of a numerous body of irrigation engineers who sincerely believe that unless certain slopes of flow were provided in different reaches of any channel, the flat sloped reaches would silt up. Personally the speaker maintained that if instead of 1/5714 the slope in the troublesome reach had been twice as flat, even then with a handsome fall at the head of the reach, water would still have flowed on without any silting trouble. This reminded the speaker of the case of the tail reach of a silting channel in Sheikhupura Division, on which all expedients of silt clearances, regrading, etc., had been tried by Mr. Murphy and other engineers, but the silt trouble persisted. The

silt cleared; although it had retained a certain silted up section for many years without further silting up. These facts tended to disprove the general impression about silting and scouring phenomena, that it is the heavy intensity of silt in suspension in water and insufficient velocity of flow that are responsible for silting up of channels. Nor could Mr. Kennedy's silt theory hold good in such a case, where intensity of silt charge was extremely low, velocity (in spite of the channel being situated near the tail of a canal system) having been kept more than Mr. Kennedy's Vo, and yet within two weeks of heavy silt clearance, the channel again silted up about one foot near its head."

Shortly after finding the ineffectiveness of silt clearances the speaker suggested to the Executive Engineer, late *Khan Sahib* Faqir Mohammad Khan, to remodel the head regulators of both Teona Distributary and Doomwali Minor to flume type ones, and to artificially tighten the head reaches of these two channels, and to this suggestion the Executive Engineer kindly agreed. The results were remarkable indeed. Although the surface slopes of both channels had been considerably flattened during the remodelling in order to obtain proper working head for the minor, no silting trouble had, the speaker believed, been experienced on these channels since the last seven years, whereas, Teona Distributary had silted up in January after silting clearance done in December. The speaker had discussed this point at great length because of the fundamental importance to irrigation engineers of realizing his oft-repeated first principles of designing earthen channels, that within very wide limits we could design artificial channels as flat as the nature of the country might require, without any danger of their silting up, and that we could not make channels unduly steep without imparting to them tendencies to silt up in their head reaches, and to become wide and shallow generally.

Now to revert to the question of remodelling of channels described in the paper under discussion. The Mungi Distributary a 193 cusec channel, later reduced to 160, taking off at 143 miles from the head of the canal, and designed to a slope of 1/4444 originally, suffered from acute silting trouble; and the reason was as usual supposed to be coarse silt entering at the head of the channel, which the slope was too flat to carry. The very distance of the distributary from the head of the canal should have precluded the consideration of coarse silt as being the cause of silting trouble, because it could be in the opinion of the

author, satisfactorily proved that coarse silt did not exist in that vicinity. And yet year after year they went on either steepening the slopes of the channel or excluding the non-existent coarse silt at head, and the silting trouble continued. Extensive remodelling was done in 1934, again in 1935, and yet again in 1936; and in spite of all these measures in the words of Mr. Jesson, the distributary still continued to silt, so that he came to the conclusion that the only remedy was to steepen the slope between O to 70,000, or exclude coarse silt by constructiug King's vanes in front of the head regulator. Mr. Jesson preferred the former, as he was only prepared to resort to silt exclusion when there was no other remedy available. This attitude of the author gave an indication of the lurking feeling in his mind that silt exclusion could do no good. The steepening of the slope of the distributary was carried out in 1938, and the distributary worked extremely well since April 1938. No wonder that after five years of remodelling work the distributary had started working well, and no wonder that Mr. Jesson had it in mind that if at a later date the channel started to silt, he would be inclined to consider tightening it, as the tightening of the Mithalak Distributary was so successful. Same is the story of the other two distributaries described in the paper. In December, 1933, when Mr. Jesson assumed charge of the Eastern Circle, Awagat Distributary of 63 cusecs discharge was taking 65 cusecs instead, and so its remodelling was considered necessary. Kheowala Distributary a 20 cusec channel taking off nearly a hundred miles from the head of the canal, was also supposed to draw coarse silt at its head ; so it was also extensively remodelled. The result was that in the words of the author on the whole the channel worked quite well, and less silt deposited than in previous years. But as there was still a tendency to silt, Mr. Jesson in 1938, decided to re-grade the channel, and to re-adjust the outlets. Since April, 1938, the distributary had given no trouble, it must be the fervent prayer of every one of us that it would not again give trouble.

Lastly, one word about the conclusion arrived at by the author. Apart from anything else, the value of a paper which was brought up at the Engineering Congress for scientific discussion, must primarily depend on the conclusions of general applicability which the author of the paper was able to satisfactorily enunciate. On the very first page of the paper the author stated that in his opinion a different policy of remodelling was required for each canal, and that any attempt to lay down a general policy for all the canals in the Province was doomed to

failure. Furthermore, although the author considered that the time had now come for the Government to lay down a clear and definite policy for remodelling on each canal, one looked in vain in his lengthy paper for his clear and definite policy even with regard to the Lower Jhelum and the Lower Chenab Canals ; unless the author's policy was embodied in his 'Hints for Engineers undertaking Remodelling of Distributaries'. These hints dealt with the questions of constructing proper bench marks, the desirability of showing proposals on white paper plans in pencil, instead of on blue prints in vermilion, and the necessity of consulting in cases of doubt someone who had extensive experience of remodelling, etc., etc. His hint No. 10 wherein he advised that engineers should not be afraid to submit a remodelling scheme because it was expensive, must have a highly pleasant flavour for the harassed engineers of the Province, who were almost constantly goaded from above to lower the costs of works. Mr. Jesson thought it a mistake to tinker with a channel with a view to cheapen the cost of remodelling. Mr. Jesson had laid stress on the saying "what was worth doing was worth doing well." A liberal interpretation of this saying would bring about a millennium for engineers but it would be a dark day for the finances of the Province.

The speaker was very sorry indeed that he had been somewhat outspoken with his remarks. But as the subject of remodelling was of such importance to the Province, he must, in the strongest terms, express his disagreement with Mr. Jesson's opinion that a different policy of remodelling was required for each canal. A consistent set of rules of remodelling channels should be evolved based not on opinions but on a clear conception of the behaviour of flow of water in earthen channels under different conditions. It was, of course, not necessary for everybody interested in remodelling to advance a new theory of flow of water. But it was certainly of the utmost importance for them to know the fundamental laws of flow of water and the functions and behaviour of silt in flowing water. For this purpose it was not necessary for them to accept any particular theory, if they would intelligently observe the behaviour of flow of water under different conditions, and would endeavour to separate facts from superstitious ideas, particularly with regard to the prevalent notion, that it was only coarse silt that could cause silting trouble.

The speaker continued that Mr. Jesson deserved thanks for contributing his interesting paper, which had enabled the members to give expression to their different views.

He was also to be thanked for his generous offer of helping anyone who cared to consult him on the subject of remodelling. But in his humble opinion his vast experience of remodelling could be turned to much better account if he would kindly try to frame a set of rules on the scientific aspect of remodelling, such as designing channels which would not be stuck up in the air, as most of his remodelled channels unfortunately were. Such channels besides suffering from enormous percolation losses, were the most potent cause of waterlogging of the areas through which they flowed.

Mr. Jesson had mentioned that there was great necessity of a suitable constant discharge outlet. The speaker said he had devised one a long time ago, and he believed that a simpler and more effective constant discharge outlet, it would be very difficult if not impossible to devise. The existing A. P. M. outlets could be easily converted into this type of outlet at a small cost.

Mr. **K. A. Ghafoor** pointed out that on page 26, paragraph 4 of the paper, Mr. Josson had said if skimmer heads had been constructed in the East Circle, the distributaries in the lower reaches of the Lower Gogera and Burala Branches would have silted solid. This statement was likely to discourage the construction of skimmer head which was one of the most effective devices to reduce coarse silt entry into a channel.

Firstly, if allowed to go down the canal, most of the coarse silt was likely to get disintegrated into smaller and lighter particles in the process of rolling. It was known that the silt in the tail reach of a canal was much lighter than in the head reach, and also that the canals taking off lower weirs had much lighter silt than those of the upper weirs. Secondly, after she construction of the skimmer head the amount of coarse silt entering the channel could be increased if found ncessary by making a hole in the wall of the under tunnel and its amount could be regulated to a very high degree of accuracy by altering the size of the hole, whereas if it was found that the exclusion of coarse silt had not been sufficient in the type of head advocated by Mr. Jesson, nothing could be done except either scrapping that head altogether or keeping on silt clearing the channel.

The speaker stated that he had three skimmer slabs constructed some time back in one of the branches of the Bahawal Canal and found that they were very effective in reducing the coarse silt entry. In one case, one of the under-tunnels was found blocked. This was natural as the

water in the parent channel immediately in front of the head had higher silt charge on account of its exclusion from the offtake. In spite of this blocking of the tunnel, the skimmer head was functioning very satisfactorily. In another place he had built a reinforced concrete skimmer slab of cantilever type, which did not cause any deposit of silt under the slab, evidently due to the absence of posts or piers.

As pointed out by Mr. Jesson, silting in most of the channels was usually due to the defective head regulator. The main defect noticed was the low crest, which caused coarse silt entry into the channel. During the early years of development of a new canal, the crests of heads of offtakes had to be necessarily low, as the canal ran with a smaller supply and at a level much lower than the designed for many years. Naturally the original designer who prepared the project expected that the engineers that came after him would see to the raising of crests wherever necessary without blaming him for the low crests.

The conditions required for preventing excessive silt entry could be summarized into the following three points :—

(1) The head regulator should have a raised crest above the bed level of the parent channel,

(2) Smooth entry of the supply without eddy action, and

(3) Entry of the supply with a velocity proportionately lower than that of the parent channel.

Any device or type of head regulator that fulfilled these three conditions would put a stop to excessive silt entry. So the speaker suggested finding out of the particular defect in the head regulator and removing the same instead of scrapping the existing one altogether. Wholesale scrapping should be the last resort.

The speaker referred to page 3 of the paper, paragraphs 3 to 5 which read as below:—

> " In 1907 one of the three bays was closed, and a masonry wall was constructed across the front of the regulator and the top of the wall was 3' above the bed of the branch. The Engineer-in-charge apparently thought that this wall would exclude heavy silt. But the distributary continued to silt and there was serious shortage at the tail."

The speaker contended that the 3 ft. high wall would have certainly stopped the coarse silt entry, had one more bay been added, instead of closing one bay. By closing one bay, the reduced water-way must have increased the velocity of entry, which naturally helped sucking in of silt.

Mr. Jesson had in several places in his paper referred to tightening of the channel where it was too wide. The speaker thought that tightening without reducing the silt entry from the head was bound to result in a failure, because the tendency of the channel to get wider and shallower was natural if it was getting excess of silt. This was seldom realized, and tightening of channels was often resorted to. By reference to Kennedy's and Lacey's Diagrams, it would be noticed that for a given slope and a given discharge, the wider the channel the higher the C. V. R. or the value of "f". Therefore if without reducing silt entry into the channel one started contracting it, either his attempt would result in a failure or the channel in that reach would adopt a still steeper slope causing more trouble. So tightening of channels should not be resorted to specially if the bed was found to be fairly uniform. If, however, meandering of the main current in a straight reach of a channel was noticeable, that could be taken as an indication that the channel required tightening.

Lastly, the speaker suggested that while preparing remodelling schemes attempt should be made for grouping of outlets into clusters just upstream of a fall by shifting them some distance up or downstream and introducing a fall if one did not exist at a possible grouping site. This was strongly advocated, as firstly, this resulted in a most equitable distribution, and secondly, the channels with such distributors assumed regime very quickly.

Mr. **G. R. Sawhney** said that the Congress, and more specially the Irrigation Engineers, should be very grateful to the author for producing a very good paper on the most important subject which was constantly confronting engineers on the running Canals.

Most of the troubles in this connection were due to the fact that the poor Irrigation Engineer being a mere man, not only in the past but, even now, he was apt to follow the line of least resistance and leave most of the investigation to others, and willingly accept any data that was supplied to him by a Gauge Reader or an Overseer, and more readily so if such a data happened to fit in with some pre-conceived idea of his.

He then tossed up whether to follow Kennedy, or Lacey, and remembering a few tips by Mr. Crump, the Author or other Pundits, he sat down to evolve a most wonderful scheme. But he got the shock of his life, when the channels started functioning again after his remodelling was finished. He felt staggered for a while but soon consoled himself by blaming the *Guru* that he followed, and in case he still remained in charge of this mess and had to tender any explanations, then either a wrong Bench Mark, or a loose screw of a level were ever handy to come to his rescue, and help him out of the ditch.

The Author had put this subject before the Engineers in a very practical form. It was most essential that we should now sit down and pick out his best points and also consult the various opinions already collected by Mr. C. E. Jeffries in 1938, and frame definite rules for different canals and see that their application was rigidly enforced.

The author had tabled out a dozen of most useful hints.

The pity was, that there was generally no history available, files as one finds them seldom are of much use, unless some special steps were taken to have them put together properly. To come to a correct decision as to why a channel would not work properly, was not a very easy matter, but when this could be done, the solution was quite easy.

This was not always possible, as in some cases the condition of the already short tails was likely to become worse, and that should not be allowed to happen.

It might not be possible to frame rules which could literally be followed on all the canals, but different methods and ideas that were being introduced by different engineers; each one trying to go one better than the other, had resulted in frightening the Zamindars of the "Remodelling-Monster."

The speaker suggested that at least the same sort of forms technique should be used all over the Province, and a Standard Portable Flume supplied to each Sectional Subordinate. Fixing of F. S. L. for as many channels as possible should also be done everywhere immediately.

If the Executive Engineer carefully looked at the 'H' or the Outlet Gauge Register regularly and enquired into the causes of all ups and downs promptly and did not allow much interference from the Zamindars, or carelessness on the part of the staff went unpunished, the speaker was of the opinion that in most cases the channels would

somehow or other give up the nasty habit of wanting to change their supply levels too often.

Reasons given by the Author were very convincing. The speaker said that the raising of banks should be very much restricted, and as far as possible, wherever necessary. it should be done in a closure. As for some reason to other each time an estimate for raising banks was sanctioned and work done, the bed of the channel and the F. S. L. invariably raised themselves.

The only trouble of continuous silt clearance which the speaker could foresee, would be the difficulty in disposal of the silt that would have to be cleared.

The speaker said, that until some way of dissecting sand proportionately to the other dimension was devised, such model experiments on Regulators were likely to lead us astray. He suggested that Research Department should, instead of doing model experiments, devise ways and means of carrying out detailed experiments under strict supervision at the site of various types of Regulators.

The speaker said that on minutely studying the working of various channels, he had noticed that curves had a very material effect on upsetting their sanctioned slopes. He suggested that complete information regarding curves should also be shown on all Long Sections. A study of the effect that the various curves might have on the Outlet Gauges, would soon show the usefulness of having this information.

Constant removal of all silt heaps or other obstacles near outlet sites, ghat sites or bridges, syphons, etc., during the short closures in winter, went a long way to help in equitable distribution of water. The speaker had tried ploughing of the bed in reaches in which gauges were higher than designed, during the winter months, both before opening of channels, and also when the channels were actually in flow and had obtained very satisfactory results. The speaker said he was trying to get a special plough made for this purpose. This ploughing if done when the Longitudinal Bushing was being put in a channel to tighten it to designed section, helped in getting very quick result, and at the same time in keeping the supply level down in these reaches which otherwise would go up considerably. By using this inexpensive method, a good deal of silt clearance could also be saved. The speaker said that he had just lowered the bed of Gamber Distributary from R. D. 25000 to 35000 by depths varying from 0'9 ft. to 1'3 ft. by bushing and ploughing since December last only.

The speaker remarked that instead of believing in author's advice "If at first you don't succeed, try, try, try, again" he would say, try so hard in the first instance that one does not have to do too many tries, because by trying again and again we are apt to give a very poor show of ourselves to the now critical Zamindars and other Departments that are connected with us.

The speaker added that the author's energy, strength of his convictions, his rigidity, and his fearless use of authority were the main cause of his successful remodelling; and not merely the following of a set of any rules.

Replying the **Author** said that he was delighted to hear the discussion from Mr. Lyster that it was a revelation to him to return to the East Circle in 1938, and see the improvements effected.

He was also glad to see that Mr. Lyster advocated central control of remodelling, or, as an alternative, the retention of the Superintending Engineer until the remodelling was complete.

In reply to *Khan Bahadur* Sheikh Minhaj-ud-Din the author pointed out that the increase in the silt deposits in the tail reach of the Northern Branch of the Lower Jhelum Canal was, in his opinion, not due to silt exclusion from distributaries, but to silt exclusion at Rasul. Due to the adoption of the still pond method of regulation at Rasul since 1932, the coarse silt charge of the water entering the canal had decreased, and this had caused silt to be picked up from the bed of the main canal and branches, and to be carried down to the tail reaches. This was only a passing phase, and was also occurring on the Lower Chenab Canal.

In reply to the criticism on the design of outlets, the author said that, in his opinion, the pipe-cum–A. P. M. or open flume outlet was better than a bend outlet.

The hydraulic regime of a channel would not be adversely affected, if a few outlets were set with their crests above bed level, but the result would be disastrous if many were set with high crests.

Deep set open flume outlets were permissible above the control points, but A. P. Ms. are better.

As a general rule, the crest of an A. P. M. outlet should be set as deep as the working head available permitted.

With reference to the criticism about the position of the hole into the gauge well of a meter flume, placing the hole in the upstream face of the wing wall would eliminate

" h_a" in the discharge formula, and affect the co-efficient. The author had found by experience that the position advocated in the type design was the best, and that there was no draw down in the water surface at this point.

The *Khan Bahadur's* suggestion regarding "H" graphs being prepared by the Sub-Divisional Officer, and submitted with the yearly efficiency diagrams, was not suitable in the author's opinion as these graphs must be prepared every month.

Mr. B. L. Uppal had offered much criticism, but due to lack of space, the author regretted that he could only reply to a few points.

In the author's opinion the head regulator of a distributary taking off a main or branch canal should be so designed that it would draw off as much coarse silt as the distributary could accommodate without silting. For this reason the author advocated extensive experiments on model head regulators in order to ascertain the best design.

The agitation that took place in the East Circle in 1938 was organized by interested persons, who wished to catch the cultivators' votes. It was not justified, as the outlets had not been touched since 1934, and the adjustments carried out in 1938 were small.

Mr. Uppal had offered very destructive criticism on the remodelling of Mungi Distributary.

Perhaps he would have succeeded in remodelling the distributary at the first attempt. Unfortunately the author, inspite of his experience, failed to succeed at the first attempt, and he did not mind admitting it, but in the end he succeeded, where others had failed. As a result of this the zamindars on this Distributary were quite happy, especially those in the tail reach. Surely it was better to try again, until success was obtained, than to leave the remodelling incomplete.

Some form of regulation was obviously necessary at the head of this Distributary, so that it might draw off full supply during its turn, when short supply was running in the parent channel. The author preferred needle regulation,

In his comments on the Awagat Distributary, Mr. Uppal referred to the long crest, and made other comments on the design of this work. This head regulator was not designed as a headless flume. With no afflux, the regulator would pass full supply discharge into the channel with a velocity of 2 feet per second whereas the normal velocity in

the channel is only 1.8 feet per second. Admittedly the length of the crest could have been reduced by 15′, but, when this design was prepared, the optimum position for the gate was not known.

Admitting that a meter flume in the head reach of each distributary was desirable, Mr. Uppal would, the author said, agree that the water level in the head reach of Awagat Distributary could not be lowered, if he had inspected the site, and discussed the matter with the author. Experience showed that this channel did not suffer during short supplies. If in future it was found to suffer, the crest of the meter flume at R. D. 1,900 could be lowered by a few inches.

Commenting on the Kheowala Distributary, Mr. Uppal expressed the opinion that the crest of the head regulator should be lowered to ensure command during low supplies in the parent channel, but he forgot that there was a control point with needle regulation in the parent channel at the offtake of this Distributary.

In the matter of longitudinal sections Mr. Uppal preferred design forms. This was a matter of taste. The author, and probably most engineers, preferred a picture.

Referring to Mr. Foy's comments, which were made by Mr. Haigh in Mr. Foy's absence, the author would say that, since the remodelling of the Headworks at Khanki, silt exclusion at the head of the canal had been most effective, as the main line of the Lower Chenab Canal had scoured down to the original designed bed.

The majority of the coarse silt, that had scoured out, had passed down the Upper Gugera Branch, and thence into the two branches taking off at Buchiana, and was now causing trouble in the distributaries. As in the case of the Lower Jhelum Canal, this was a temporary phase, and a time must come, when this coarse silt would disappear due to silt clearance, or to the fact that the silt had passed into the watercourses. It remained to be seen what the regime slopes would be, when this occurred, and the author would be interested to hear in due course. On the Lower Jhelum Canal, due to adopting the still pond method of regulation at Rasul since 1932, there were already indications that the distributaries in the upper reaches were flattening their slopes.

Referring to Mr. S. L. Malhotra's remarks, the author maintained that it was impossible to design a non-silting channel on the Lower Jhelum Canal with a slope of 1/5714, and a discharge of 60 cusecs, and, therefore, silt

clearance was necessary, as the slope could be increased without losing command of the Sargodha Civil Station.

Apparently Mr. Malhotra had not read the paper very carefully, as if he referred to pages 23, he would see that the author recommended artificial contraction with bushing only when a channel was abnormally wide,

In commenting on the proposed hydraulic data, Mr. Malhotra forgot that in every case in the East Circle of the Lower Chenab Canal the head regulator of the channel was remodelled, so the hydraulic data of the channel must alter. The proposed hydraulic data had to be assumed, and this was where experience of remodelling became most valuable. The author's method was not to fix an arbitrary C. V. R., and force the channel to adopt it. The method adopted was to fix a C.V.R. that in the author's opinion would be suitable, and then watch the working of the channel, and remedy any defects that were found. Generally speaking very few changes had been made.

Referring to the Mithalak Distributary, the author would point out that he tightened the channel, because it was abnormally wide, and experience had shown him that such a wide channel would not work satisfactorily. As the Mithalak Distributary was now working extremely well, the tightening was justified.

Mr. Malhotra had confused bushing and spurs on a branch canal with those on distributaries. The author had never attempted to spur or bush a branch canal, as to do so would, in his opinion, be a waste of money.

Referring to imdadi pipes, such pipes were only given as a temporary measure till the water level in the channel rose to its designed level.

In reply to Mr. R. K. Khanna, the author would say that prior to 1932 the Lower Jhelum Canal did draw off coarse silt due to the open pond method of regulation adopted at Rasul.

The Mithalak Distributary had always given trouble, until it was remodelled during the author's incumbency of the Lower Jhelum Canal Circle. Supplies in excess of the authorized had to be run at the head, and outlets had to be tailed to get water to the tail.

Undoubtedly Mr. Khanna's suggestion that a flat slope in the head reach, gradually steepening towards the tail was the ideal, but in the case of Mithalak Distributary this was not feasible.

The author regretted that he could not accept Mr. Khanna's statement that a distributary on the Upper Chenab Canal worked without any slope.

Regarding Mr. Khanna's remarks on the Mungi Distributary, the author would refer him to the table at page 27 of the paper. This showed that coarse silt did exist in the vicinity.

Regarding a general policy for remodelling, the author said that most engineers would agree that a single policy for all canals in the Punjab was not feasible. The author would be interested to read and criticise any paper by Mr. Khanna on a single remodelling policy that could be applied to all canals in the Punjab.

Perhaps Mr. Khanna did not read the author's remarks on pages 24 and 25 of the paper, in which he had made a definite recommendation regarding the remodelling policy to be adopted on the Lower Chenab Canal.

Mr. **Ghafoor** referred to skimmer heads, and considered that they were one of the most effective devices to reduce coarse silt entry into a channel. The author admitted this, but considered that the adoption of this type of head regulator required most careful consideration. This type of head should only be adopted, when all other devices to make the channel work satisfactorily had failed.

Some years ago Dr. Bose told the author that, in his opinion, coarse silt did not disintegrate into smaller particles in its passage down a canal. The reason for finer silt in the tail reaches of the majority of canals was that the offtaking channels in the upper reaches had drawn off the coarse silt. With the type of head regulator advocated by the author, more silt could easily be excluded by constructing King's vanes.

The author entirely agreed with Mr. Ghafoor's three conditions for preventing excessive silt entry into an offtaking channel. Generally speaking he found that the mean velocity in the flume of the head regulator should be slightly less than in the side segment of the parent channel.

The author was afraid that Mr. Ghafoor's suggestion, that one bay should have been added in 1907 to the head regulator of the Mithalak Distributary, would not have cured the trouble. Mr. Woods added an extra bay, when he remodelled the head regulator of this Distributary, but the silt trouble was not cured owing to

the eddy action that took place in front of the head regulator.

With reference to Mr. Ghafoor's remarks regarding tightening of channels, the author agreed that tightening should be accompanied by remodelling the head regulator. In every case in the East Circle, the head regulator was remodelled before tightening of the channel was tackled.

The author also agreed with Mr. Ghafoor's suggestion about grouping outlets above a fall. This should always be done where feasible, but unfortunately, in most cases, it was difficult to put in many control points on a distributary, as slopes in the Punjab were generally insufficient.

Referring to Mr. G. R. Sawhney's remarks, the author stated that it would be impossible to adopt the same forms and technique for remodelling on all canals.

Mr. **Sawhney** had referred to a difficulty connected with frequent silt clearances, *viz.*, the disposal of the silt. In the author's opinion, such silt clearances were not likely to be necessary on many distributaries. In abnormal cases additional land must be acquired, on which the silt might be dumped.

The author agreed that the removal of silt heaps and other obstacles in the bed of a channel did help in maintaining regime. This was actually demonstrated in the case of a distributary in the Jhang Division of the West Circle. The author, however, did not agree with ploughing the bed of a distributary. If silt clearance is necessary, the silt should be excavated in the usual way.

Mr. **Sawhney's** remarks regarding " try try again " were interesting. Perhaps with a little more experience he would be able to remodel distributaries successfully at the first attempt. If he could do so, the author would be delighted to know the results.