急流渠道斗門之設計

Design of Turnouts in Super Critical Flow Channel

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一、引　言

斗門 (Turnout) 爲灌溉渠道內常用的構造物，用以自幹渠分水入支渠或副支渠。除非大型結構，大部份的斗門爲利用有覆蓋之管路，如圓管或箱型閉管，穿過堤岸。通常，斗門下游具有節制閘 (check gate) 以維持所需要之水深，否則，斗門進水的明渠或導管必須夠大並須低置至相當程度，即在渠道中僅有一半容量時亦能輸出所需之水量。一般斗門的位置以設置於緩流 (Sub-critical flow) 渠道內較爲適宜，然而，在急流渠道內不得不設置斗門之情形亦所難免，此時所發生的困難爲：

1. 急流渠道內常因流速過大，水流難以轉向 (斗門方向常與渠道方向成爲垂直)，致使分水困難。

2. 急流渠道內常因水深過淺，無足夠水深供其分水，若將斗門設置過低，灌溉面積勢必減少。

針對上述困難，本文就一種適合於急流渠道之斗門構造物說明其設計概要與步驟。

二、設計概要

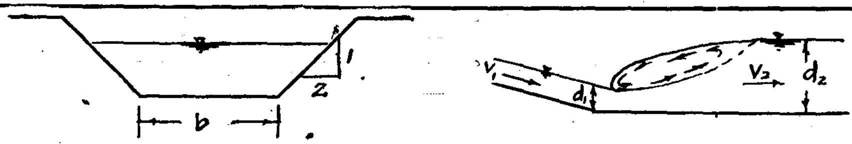
1. 原則：此種斗門，其本身構造與一般斗門並無差異。但將急流渠道在斗門位置上游設置一段水平部份，使渠道內水流在此平坦部份發生水躍 (Hydraulic Jump) 以減小流速並增加水深，待其變成緩流以後始流到斗門位置而適於分水。又爲發生完全的水躍，分水斗門下游必須設置一控制斷面 (control section) 或節制閘加以控制，使不受下游急流之影響。所以設置斗門處之渠道將可分爲緩流段，分水斗門，控制段及漸變段四部份，請見設計例內圖四。

2. 緩流段

A. 斷面形狀：此段爲水流發生水躍，自急流狀態變爲緩流的一段，緩流段亦如一般渠道採用梯形，以節省工費 (無需模型板及鋼筋)，其邊坡、底寬均與上游急流渠道相同，但渠底坡度設爲水平。

B. 低水深與高水深：水流既在此段發生水躍，其跳水高度必須計算，若水躍之低水深 (d_1) 爲已知則其高水深 (d_2) 亦可算出。此處，水躍的低水深即爲急流渠道內之水深，其高水理可用水理公式求得，但爲節省計算上之繁雜，由已成之表圖查算較爲方便，請參照表一。

表一　梯形斷面之水躍



$$H_1 = d_1 + \frac{V_1^2}{2g}$$

$\frac{d_1}{H_1}$	Value of d_2/H_1								
	$\frac{b}{Zd_1}=0$ Δ型	$\frac{b}{Zd_1}=\frac{1}{2}$	$\frac{b}{Zd_1}=1$	$\frac{b}{Zd_1}=2$	$\frac{b}{Zd_1}=4$	$\frac{b}{Zd_1}=10$	$\frac{Zd_1}{b}=0.05$	$\frac{Zd_1}{b}=0.02$	$\frac{Zd}{b}=0$ U 型
0.02	0.132	0.146	0.158	0.172	0.192	0.216	0.242	0.254	0.268
.04	.208	.228	.244	.260	.286	.320	.340	.358	.374
.06	.270	.294	.312	.332	.360	.396	.416	.432	.448
.08	.324	.350	.368	.396	.420	.460	.472	.492	.504
.10	.370	.400	.418	.450	.476	.512	.528	.544	.552
.12	.414	.444	.464	.496	.524	.558	.572	.584	.592
.14	.454	.488	.508	.534	.564	.594	.608	.622	.628
.16	.494	.526	.546	.572	.600	.630	.642	.652	.658
.18	.530	.560	.584	.608	.634	.660	.670	.678	.682
.20	.562	.594	.616	.638	.664	.686	.696	.702	.706
.22	.592	.622	.646	.666	.690	.710	.716	.724	.726
.24	.618	.652	.672	.692	.712	.730	.734	.740	.742
.26	.646	.676	.696	.714	.732	.748	.750	.756	.758
.28	.670	.700	.718	.734	.750	.764	.764	.768	.770
.30	.694	.722	.738	.754	.766	.778	.778	.780	.780
.32	.716	.740	.756	.772	.782	.788	.788	.788	.786
.34	.736	.760	.774	.788	.794	.798	.796	.796	.792
.36	.754	.776	.788	.800	.804	.806	.804	.800	.796
.38	.772	.792	.802	.812	.814	.811	.806	.804	.799
.40	.790	.806	.814	.820	.820	.814	.808	.805	.800

.42	.804	.818	.826	.828	.825	.816	.810	.804	.799
.44	.818	.830	.834	.834	.828	.816	.808	.802	.796
.46	.830	.840	.842	.838	.830	.815	.806	.798	.792
.48	.842	.848	.848	.842	.829	.812	.802	.794	.786
.50	.852	.856	.852	.844	.828	.806	.796	.788	.780
.52	.860	.862	.854	.844	.824	.800	.788	.780	.772
.54	.866	.866	.854	.842	.818	.792	.786	.772	.762
.56	.872	.865	.852	.838	.812	.784	.768	.760	.750
.58	.876	.866	.850	.830	.802	.776	.756	.748	.738
.60	.877	.864	.846	.822	.792	.760	.742	.734	.724
.62	.878	.860	.840	.812	.780	.744	.728	.718	.708
.64	.878	.854	.832	.800	.766	.728	.712	.702	.692
.66	.876	.846	.822	.788	.750	.710	.694	.682	.674
.68	.872	.838	.810	.772	.732	.692	—	—	—
.70	.866	.826	.796	.754	.712	—	—	—	—
72	.858	.814	.778	.734	—	—	—	—	—
.74	.846	.798	.760	—	—	—	—	—	—
.76	.834	.778	—	—	—	—	—	—	—
.78	.818	—	—	—	—	—	—	—	—
d_c / H_1	.800	.769	.750	.727	.706	.686	.677	.671	.667

S. M. Woodward and C.J. Posey Hydraulics of steady flow in open channels 1951 Page 45 Table 402.

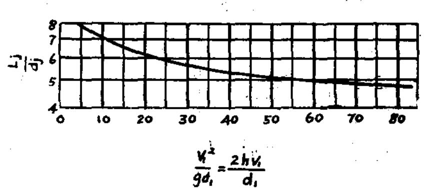
C. 長度：緩流段的長度，須先考慮發生水躍所需長度（Lj），圖一，表示$\frac{V_1^2}{gd_1}$與$\frac{Lj}{d_j}$之關係，除$\frac{V_1^2}{gd_1}$大於60，$\frac{Lj}{d_j}$通常用5外，其餘可自圖上關係曲線求得。此處，

$d_j = d_2 - d_1$

d_1＝水躍低水深，V_1＝低水深時的流速

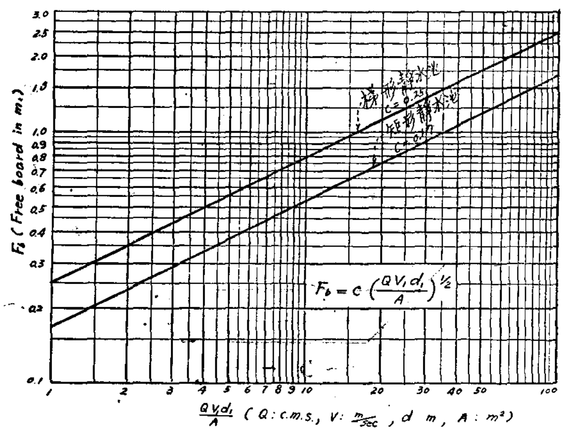
d_2＝水躍高水深，g＝重力加速度（9.8m/sec²）

通常爲分水順利，斗門宜設置在發生水躍下游二至三公尺處，如此，緩流段長度應採用發生水躍所需長度再加二至三公尺。



圖一 $\frac{Lj}{d_j}$與$\frac{V_1^2}{gd_1}$之關係

D. 出水高度：（Free board）：緩流段的作用與一般跌水工（Drop）或徙坡（Chute）的靜水池（stilling pool）相似，故可比照此種靜水池，採用適當的出水高度。圖二，表示$\frac{QVd}{A}$值與出水高度之關係，在$\frac{QVd}{A}$公式中，用急流渠道之流速及水深。



圖二 出水高度與$\frac{Q\ V_1d_1}{A}$之關係

3. 分水斗門：小型結構的分水斗門，大部份爲利用有覆蓋之管路，如圓管或箱型閉管穿過堤岸，其管大小及設置高程，可按潛流孔口（Submerged Orifice）以作水工設計，其流量公式如下：

$$Q = CA\sqrt{2gh} \quad \cdots\cdots\cdots (1)$$

其中，

Q＝流量，以秒立方公尺計，接近流速不加計算

A＝管的斷面積，以平方公尺計

g＝重力加速度（9.8m/sec²）

h＝管路上、下游兩端之水位差，以公尺計

C＝流量係數，一般採用 0.7（依管路長短及形狀，有時須加予修正）

4. 控制段

A. 控制斷面與節制閘： 分水斗門下游通常仍爲急流渠道，水流在進入急流渠道以前，如無節制閘或控制斷面予以控制，則緩流段所發生之水躍將受下游急流所影響，並於斗門處無法維持所需要的水深，而節制閘常因增加工費或需用人工加以操縱等問題不適於設置，故採用一種控制斷面較爲理想，但分水斗門邊牆仍設有插板槽，遇有需要時亦可用插板調節水流以期完善。

B. 控制斷面之計算符號

A：流水斷面積（m^2）

A_c：控制斷面之流水斷面積（m^2）

a：臨界水深與比能之比，

B：水路底寬（m）

B_c：控制斷面之底寬（m）

d：水路之水深（m）

d_c：相當於流量 Q之臨界水深(m)

E：比能，$d+h_v$，d_c+h_c

g：重力加速度 $9.8\frac{m}{sec^2}$

h_v：流速水頭（m）

h_c：控制處之流速水頭（m）

K：$(\frac{Q^2}{g})^{1/3}$

M：某式之簡號

N：某式之簡號

n：粗糙係數

Q：流量（$\frac{m^3}{sec}$）

S：水路之邊坡（橫比豎）

T：水面寬（m）

T_c：控制處之水面寬（m）

C. 控制斷面之計算式及決定

流水斷面A爲

$$A=\left\{\frac{1}{2}(T+B)\right\}d \quad\cdots\cdots(2)$$

但在矩形斷面 $T=B$，三角形斷面$B=O$

一般於任何斷面，其臨界水深之條件爲

$$\frac{Q^2}{g}=\frac{A_c^3}{T_c} \quad\cdots\cdots(3)$$

A_c 用（2）式代入，得

$$\frac{Q^2}{g}=\frac{(T_c+B_c)^3}{8T}\cdot d_c^3 \quad\cdots\cdots(4)$$

控制斷面之流速水頭

$$h_c=\frac{A_c}{2T_c} \quad\cdots\cdots(5)$$

由(3)，(4)，(5)三式，可得下式

$$d_c=\frac{(\frac{Q^2}{g})^{1/3}\cdot 2T_c^{\ 1/3}}{T_c+B_c}=\frac{2K\ T_c^{\ 1/3}}{T_c+B_c}$$

$$=aE \quad\cdots\cdots(6)$$

$$\text{但}\quad K=\left(\frac{Q^2}{g}\right)^{1/3}$$

$$h_c=\frac{V_c^2}{2g}=\frac{Q^2}{2g\ A_c^2}=\frac{2\ Q^2}{g(T_c+B_c)^2 d_c^2}$$

$$=\frac{2\ K^3}{(T_c+B_c)^2}\cdot\frac{(T_c+B_c)^2}{4\ K^2\ T_c^{\ 2/3}}$$

$$=\frac{K}{2\ T_c^{\ 2/3}}=(1-a)E \quad\cdots\cdots(7)$$

$$T_c=\left\{\frac{1}{2\ (1-a)}\right\}^{3/2}\left\{\frac{K}{E}\right\}^{3/2} \quad\cdots\cdots(8)$$

$$d_c(1-a)=h_c\,a\ \text{或}\ \frac{2\ K\ T_c^{\ 1/3}}{(T_c+B_c)}(1-a)$$

$$=\frac{Ka}{2\ T_c^{\ 2/3}} \quad\cdots\cdots(9)$$

$$a=\left(\frac{4\ T_c}{T_c+B_c}\right)(1-a) \quad\cdots\cdots(10)$$

$$B_c=T_c\left\{\frac{4(1-a)}{a}-1\right\}=\left\{\frac{1}{2(1-a)}\right\}^{3/2}$$

$$\left\{\frac{4(1-a)}{a}-1\right\}\left\{\frac{K}{E}\right\}^{3/2} \quad\cdots\cdots(11)$$

$$S=\frac{T_c-B_c}{2\ d_c}=\frac{T_c-T_c\left\{\frac{4(1-a)}{a}-1\right\}}{2a\ E}$$

$$=\left\{\frac{1}{2(1-a)}\right\}^{3/2}\left\{2-\frac{4(1-a)}{a}\right\}$$

$$\frac{K^{3/2}/E^{5/2}}{2a} \quad\cdots\cdots(12)$$

$$\text{設}\quad M=\left\{\frac{1}{2(1-a)}\right\}^{3/2}\left\{\frac{4(1-a)}{a}-1\right\} \cdots(13)$$

$$N=\left\{\frac{1}{2(1-a)}\right\}^{3/2}\left\{2-\frac{4(1-a)}{a}\right\}$$

$$\cdot\frac{1}{2a} \quad\cdots\cdots(14)$$

$$\text{則}\quad B_c=M\left(\frac{K}{E}\right)^{3/2} \quad\cdots\cdots(15)$$

$$S=N\left(\frac{K^{3/2}}{E^{5/2}}\right) \quad\cdots\cdots(16)$$

用下列公式計算未知數頗爲便利

$$\frac{M^{5/3}}{N}=\frac{B_c^{\ 5/3}}{KS} \quad\cdots\cdots(17)$$

$$Ma^{3/2}=B_C\left(\frac{d_C}{K}\right)^{3/2} \quad \cdots\cdots\cdots\cdots\cdots \quad (18)$$

$$Na^{5/2}=S\left(\frac{d_C{}^{5/2}}{K^{3/2}}\right) \quad \cdots\cdots\cdots\cdots\cdots \quad (19)$$

M，N，$\frac{M^{5/3}}{N}$，$Ma^{3/2}$ 及 $Na^{5/2}$ 値（a=0.10～0.80）如表二

表二 M, N, $\frac{M^{5/3}}{N}$ $Ma^{3/2}$,及$Na^{5/2}$値（a=0.10～0.80）

a	M	N	$\frac{M^{5/3}}{N}$	$Ma^{3/2}$	$Na^{5/2}$	a	M	N	$\frac{Ma^{3/2}}{N}$	$Ma^{3/2}$	$Na^{5/2}$
.10	14.50	-70.41	- 1.22	.46	- .22	.692	1.614	.329	6.76	.929	.130
.20	7.41	-17.29	- 1.63	.66	- .31	.693	1.604	.342	6.42	.925	.136
.25	5.99	-10.89	- 1.81	.75	- .34	.694	1.595	.356	6.11	.922	.142
.30	5.03	- 7.38	- 2.00	.83	- .36	.695	1.585	.370	5.82	.918	.148
.35	4.34	- 5.23	- 2.21	.90	- .38	.696	1.575	.384	5.55	.915	.155
.40	3.80	- 3.80	- 2.44	.96	- .385	.697	1.566	.398	5.30	.911	.161
.45	3.37	- 2.78	- 2.72	1.02	- .38	.698	1.556	.412	5.07	.907	.167
.50	3.00	- 2.00	- 3.12	1.061	- .354	.699	1.546	.426	4.85	.903	.173
.51	2.93	- 1.86	- 3.22	1.068	- .346	.700	1.536	.440	4.65	.900	.180
.52	2.86	- 1.73	- 3.34	1.073	- .338	.701	1.526	.454	4.46	.896	.187
.53	2.80	- 1.60	- 3.46	1.078	- .328	.702	1.517	.463	4.28	.892	.193
.54	2.73	- 1.48	- 3.61	1.082	- .317	.703	1.507	.482	4.11	.888	.200
.55	2.66	- 1.36	- 3.77	1.086	- .304	.704	1.496	.497	3.95	.884	.206
.56	2.60	- 1.24	- 3.97	1.088	- .290	.702	1.487	.511	3.79	.880	.213
.57	2.53	- 1.12	- 4.20	1.089	- .274	.706	1.477	.525	3.65	.876	.220
.58	2.46	- 1.00	- 4.48	1.088	- .257	.707	1.467	.540	3.51	.871	.227
.59	2.40	- .89	- 4.82	1.087	- .238	.708	1.456	.555	3.38	.867	.234
.60	2.33	- .78	- 5.27	1.083	- .217	.709	1.446	.569	3.25	.863	.241
.61	2.26	- .66	- 5.87	1.087	- .193	.710	1.435	.584	3.13	.858	.248
.62	2.19	- .55	- 6.72	1.070	- .166	.711	1.424	.598	3.02	.854	.255
.63	2.12	- .44	- 8.03	1.060	- .137	.712	1.414	.613	2.91	.846	.263
.64	2.05	- .32	- 10.3	1.048	- .105	.713	1.403	.629	2.80	.844	.270
.65	1.97	- .20	- 15.3	1.033	- .069	.714	1.392	.644	2.70	.839	.277
.660	1.892	- .0819	- 35.3	1.015	- .029	.715	1.381	.659	2.60	.835	.285
.661	1.883	- .0697	- 41.2	1.013	- .025	.716	1.371	.674	2.51	.830	.293
.662	1.875	- .0575	- 49.6	1.011	- .020	.717	1.360	.690	2.42	.825	.300
.663	1.867	- .0452	-662.6	1.009	- .016	.718	1.348	.705	2.33	.820	.308
.664	1.859	- .0329	- 85.4	1.006	- .012	.719	1.337	.721	2.25	.815	.316
.665	1.851	- .0206	-135.	1.003	- .007	.720	1.326	.737	2.17	.809	.324
.666	1.838	0	∞	1.00	0	.721	1.314	.753	2.10	.804	.332
.667	1.835	.00405	679.	1.00	.001	.722	1.303	.768	2.02	.799	.340
.668	1.826	.0166	164.	.997	.006	.723	1.291	.784	1.95	.793	.348
.669	1.818	.0290	63.3	.995	.011	.724	1.280	.800	1.88	.788	.357
.670	1.809	.0148	64.3	.993	.015	.725	1.298	.817	1.82	.782	.365
.671	1.800	.0543	48.9	.990	.020	.726	1.256	.833	1.75	.777	.374
.672	1.792	.0669	39.3	.988	.025	.727	1.244	.849	1.70	.771	.382
.673	1.783	.0795	32.8	.985	.029	.728	1.232	.865	1.64	.765	.391
.674	1.774	.0922	28.1	.983	.034	.729	1.220	.882	1.58	.759	.400
.675	1.766	.105	24.5	.980	.039	.730	1.208	.899	1.53	.753	.408
.676	1.757	.118	21.7	.977	.044	.731	1.196	.915	1.47	.747	.417
.677	1.748	.131	19.4	.975	.049	.732	1.184	.932	1.42	.741	.426
.678	1.739	.143	17.5	.972	.054	.733	1.171	.949	1.37	.735	.436
.679	1.730	.156	15.9	.969	.059	.734	1.159	.966	1.33	.728	.445
.680	1.722	.169	14.6	.966	.064	.735	1.146	.983	1.28	.722	.454
.681	1.713	.182	13.5	.964	.069	.736	1.133	1.001	1.23	.715	.464
.682	1.704	.195	12.4	.961	.075	.737	1.120	1.018	1.18	.709	.474
.683	1.695	.208	11.6	.958	.080	.738	1.107	1.036	1.14	.702	.484
.684	1.687	.222	10.8	.955	.085	.739	1.094	1.053	1.10	.695	.483
.685	1.678	.235	10.1	.952	.091	.740	1.081	1.071	1.06	.688	.504
.686	1.669	.248	9.47	.949	.096	.741	1.068	1.089	1.02	.681	.514
.687	1.660	.261	8.91	.945	.102	.742	1.055	1.107	.985	.674	.524
.688	1.651	.275	8.40	.942	.107	.743	1.041	1.125	.949	.666	.535
.689	1.642	.288	7.94	.939	.113	.744	1.027	1.144	.913	.659	.545
.690	1.633	.301	7.51	.936	.119	.745	1.014	1.162	.879	.651	.556
.691	1.623	.315	7.12	.932	.125	.746	1.000	1.181	.845	.644	.567

.747	.986	1.200	.813	.636	.577	.774	.553	1.769	.210	.376	.932
.748	.971	1.219	.781	.628	.589	.775	.534	1.793	.196	.365	.948
.749	.957	1.238	.751	.620	.600	.776	.516	1.817	.183	.353	.964
.750	.943	1.257	.721	.612	.612	.777	.497	1.841	.170	.340	.979
.751	.928	1.276	.692	.604	.624	.778	.478	1.865	.157	.328	.996
.752	.914	1.296	.664	.596	.635	.779	.459	1.890	.145	.315	1.013
.753	.899	1.316	.636	.588	.647	.780	.439	1.915	.133	.303	1.029
.754	.884	1.335	.610	.579	.659	.781	.402	1.940	.122	.290	1.046
.755	.869	1.355	.584	.570	.671	.782	.400	1.966	.111	.277	1.063
.756	.854	1.375	.558	.561	.683	.783	.380	1.991	.100	.263	1.080
.757	.838	1.396	.534	.552	.696	.784	.859	2.017	.0903	.250	1.098
.758	.823	1.416	.510	.543	.708	.785	.339	2.044	.0808	.236	1.116
.759	.807	1.437	.487	.534	.721	.786	.318	2.070	.0718	.222	1.134
.760	.791	1.457	.465	.525	.734	.787	.297	2.097	.0632	.207	1.152
.761	.776	1.479	.443	.515	.747	.788	.279	2.124	.0551	.193	1.170
.762	.760	1.500	.422	.505	.760	.789	.254	2.151	.0475	.178	1.189
.763	.744	1.521	.401	.495	.774	.790	.233	2.178	.0404	.162	1.208
.764	.727	1.543	.381	.485	.787	.791	.210	2.206	.0337	.148	1.228
.765	.710	1.565	.362	.475	.801	.792	.188	2.234	.0275	.133	1.247
.766	.694	1,586	.343	.465	.815	.793	.166	2.262	.0220	.117	1.267
.767	.677	1.609	.324	.454	.829	.794	.143	2.291	.0170	.101	1.287
.768	.660	1.631	.307	.444	.843	.795	.120	2.320	.0125	.085	1.308
.769	.642	1.653	.289	.433	.857	.769	.0963	2.349	.0086	.068	1.328
.770	.625	1.676	.272	.422	.872	.797	.0729	2.379	.0053	.052	1.349
.771	.607	1.699	.256	.411	.887	.798	.0487	2.409	.0027	.035	1.371
.772	.588	1.722	.240	.400	.902	.799	.0245	2.440	.0009	.018	1.392
.773	.571	1.745	.225	.388	.917	.800	0	2.471	0	0	1.414

梯形控制斷面，有關六個項目Q，B_C，E，d_C，h_C及S中若決定三個項目，其餘未知三個項目即可查表二而得，但此種控制斷面僅適合一種流量。普通，水路內的流量常因各種原因或需要而發生變化，圖三為求一控制斷面之B_C及S值，合于兩種水流情形之用。已知較大之Q_1，E_1及較小的Q_2，E_2，求控制斷面之底寬及邊坡。任何兩個a值均有$\frac{M_1}{M_2}$和$\frac{N_2}{N_1}$比值。$\frac{M_1}{M_2}$與$\left(\frac{K_2}{E_2}\right)^{3/2} \div \left(\frac{K_1}{E_1}\right)^{3/2}$相同，$\frac{N_2}{N_1}$與$\left(\frac{K_1^{3/2}}{E_1^{5/2}}\right) \div \left(\frac{K_2^{3/2}}{E_2^{5/2}}\right)$亦相同（因此為已知條件$B_{C1}=B_{C2}$，$S_1=S_2$）。自圖三可查得相當於$\frac{M_1}{M_2}$和$\frac{N_2}{N_1}$的a值，再自表二查得相當於a的M及N值，然後用$B_C=M\left(\frac{K}{E}\right)^{3/2}$，$S=N\left(\frac{K^{3/2}}{E^{5/2}}\right)$兩式以求$B_C$及S；如$E_2$小於$E_1$甚多，則控制斷面可較明白確定。

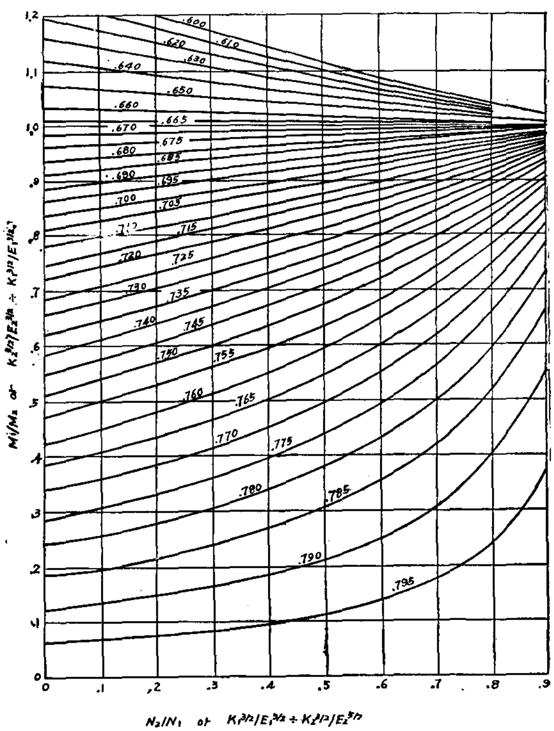
D. 控制段之長度：自分水斗門至控制斷面一段為控制段，控制斷面下游既為急流渠道，控制斷面之長度可比照徙坡入口設計準則採用，

$$\ell = 1.22 + 1.54\ Q \quad \cdots\cdots(20)$$

此處，ℓ為控制段之長度（m）

Q為流量$\left(\frac{m^3}{sec}\right)$

5. 漸變段：自控制斷面至下游渠道起點一段為漸變段，可參照一般漸變槽設計。



圖三 $\frac{M_1}{M_2}$與$\frac{N_2}{N_1}$對於a值之關係

6. 緩流段上游急流渠道之堤岸加高

因水流在緩流段發生水躍，其水路堤岸高度通常

比上游急流渠道爲高。爲安全計，此段堤岸高度需延長至上游急流渠道邊坡交點爲止，若上游渠道坡度爲S，緩流段與上游水路堤岸高度差爲 h (m) 則應加高堤岸之水路長度爲

$$L=\frac{h}{s} \cdots\cdots\cdots\cdots\cdots\cdots \quad (21)$$

三、設計步驟

1. 計算上游急流渠道在計劃流量與半流量及下游渠道在計劃流量情形下的水理因素。
2. 設計緩流段
   A.計算水躍高水深d_2計劃流量與半流量兩種情形），用表一
   B.計算跳水長度並決定緩流段長度，用圖一
   C.計算出水高度，用圖二
3. 設計分水斗門，用公式（1）
4. 設計控制段
   A.決定控制斷面的形狀，即求B_c及S，用表二及圖三
   B.決定控制段的長度，用公式 (20)
   C.計算控制斷面處渠底高程
5. 設計漸變段
   A.決定漸變段長度
   B.計算下游渠道起點高程
6. 計算上游急流渠道堤岸加高之長度，用公式(21)

四、設 計 例

1. 條件及上游渠道水理因素

水理因素	上游水路(全流量)	上游水路(半流量)	下游水路
流量 Q (c.m.s.)	0.30	0.15	0.252*
底寬 b (m)	0.30	0.30	0.30
邊坡 Z (1:Z)	1.0	1.0	1.0
水深 d (m)	0.20	0.138	0.182
流水斷面積 A (m^2)	0.10	0.0605	0.0877
水力半徑 R (m)	0.1154	0.0875	0.1075
流速 V(m/s)	3.0	2.48	2.87
流速水頭 h_V (m)	0.459	0.314	0.420
粗糙係數 n	0.014	0.014	0.014
坡度 S	1/32(=0.0312)	1/32(=0.0312)	1/32(=0.0312)
臨界水線 d_C (m)	0,328	0.227	0.30

* 分水斗門兩處，每處計劃分水量爲 q=0.024 c.m.s 故 Q=0.30−(2×0.024)=0.252 c.m.s

2. 緩流段

A.高水深 d_2

Q=0.30 c.m.s 時

$$H_1=d_1+\frac{V_1^2}{2g}=d_1+h_{V1}=0.20+0.459=0.659$$

$$\frac{d_1}{H_1}=\frac{0.20}{0.659}=0.304$$

$$\frac{b}{Zd_1}=\frac{0.30}{1\times0.20}=1.5$$

由表一，查得$\frac{d_2}{H_1}=0.75$

$d_2=0.75\times0.659=0.495$

$\frac{1}{2}Q=0.15$ c.m.s. 時

$H_1=d_1+h_{V1}=0.138+0.314=0.452$

$$\frac{d_1}{H_1}=\frac{0.138}{0.452}=0.306$$

$$\frac{b}{Zd_1}=\frac{0.30}{1\times0.138}=2.17$$

由表一，查得$\frac{d_2}{H_1}=0.76$

$d_2=0.76\times0.452=0.344$ m

B.長度

$$\frac{V_1^2}{gd_1}=\frac{(3.0)^2}{9.8\times0.20}=4.6$$

由圖一，查得$\frac{L_j}{d_j}=7.7$

$d_j=d_2-d_1=0.495-0.20=0.295$

$L_j=0.295\times7.7=2.27$ m

爲分水順利，分水斗門設置在發生水躍下游2～3m處，即緩流段長度採用 L=5.0 m

C.出水高度及堤岸高

$$\frac{QVd}{A}=V^2d=(3.0)^2\times 0.20=1.8$$

由圖二，查得出水高度 $F_b=0.33$，採用 0.376 m

$d_2=0.495$，$A_2=(0.30+0.495)\times 0.495=0.394$

$$V_2=\frac{Q}{A_2}=\frac{0.30}{0.394}=0.761 \quad h_{v2}=0.029$$

堤岸高度 $=d_2+h_{v2}+F_b=0.495+0.029+0.376=0.90$ m

3. 分水斗門

$Q=0.024$ c.m.s.……每分水斗門的分水流量

$Q=0.7\ A\sqrt{2gh}$

用管徑 $D=0.24$ m 之混凝土管，即

$$A=\frac{1}{4}D^2\pi=\frac{1}{4}(0.24)^2\times 3.14=0.0452$$

$Q=0.024$，$A=0.0452$ 代入上式，求得

$h=0.029$ m 即分水斗門導管下游之水位比水路內水位將降低 0.029 m

4. 控制段

A.求 B_c 及 S

$Q_1=0.30-(0.024\times 2)=0.252$ c.m.s.（分水後流量）

$Q_2=0.15-0.024=0.126$ c.m.s.（半流量時設僅供給一處分水斗門所需流量）

上述 Q_1 及 Q_2 之水理因素如下：

	全流量	半流量
Q (c.m.s.)	0.252	0.126
d (m)	0.495	0.344
b (m)	0.30	0.30
Z (1:Z)	1.0	1.0
A (m^2)	0.394	0.222
V (m/s)	0.64	0.567
h_v (m)	0.021	0.016
E (m)	0.516	0.360
$E^{3/2}$	0.3707	0.216
$E^{5/2}$	0.1915	0.0778
$K=\left(\frac{Q^2}{g}\right)^{1/3}$	0.1865	0.1175
$K^{3/2}$	0.0806	0.0403

$$\frac{M_1}{M_2}=\frac{K_2^{3/2}}{E_2^{3/2}}\div\frac{K_1^{3/2}}{E_1^{3/2}}=\frac{0.0403}{0.216}\div\frac{0.0806}{0.3707}=0.857$$

$$\frac{N_2}{N_1}=\frac{K_1^{3/2}}{E_1^{5/2}}\div\frac{K_2^{3/2}}{E_2^{5/2}}=\frac{0.0806}{0.1915}\div\frac{0.0403}{0.0778}=0.811$$

由圖三，查得 $a=0.746$

再由表二，查得，$M=1.0 \quad N=1.181$

$$B_c=M\left(\frac{K_1}{E_1}\right)^{3/2}=1.0\times\frac{0.0806}{0.3707}=0.217$$

$\fallingdotseq 0.22$ (m)

$$S=N\left(\frac{K_1^{3/2}}{E_1^{5/2}}\right)=1.181\times\frac{0.0806}{0.1915}=0.496$$

$\fallingdotseq 0.5$

$d_c=E\cdot a=0.516\times 0.746=0.385$

$A_c=(0.22+0.385\times 0.5)\times 0.385=0.1587$

$$V_c=\frac{0.252}{0.1587}=1.59$$

$h_{v_c}=0.129$ (m)

B.長度

$\ell=1.22+1.54\ Q$

$\ell=1.22+1.54\times 0.252=1.61$ (m) 取 1.70 m

C.控制斷面處渠底高程：控制段內之損失水頭不予考慮控制斷面處渠底高程

$=$EI. of Energy line$-(d_c+h_c)$

$=50.516-(0.385+0.129)$

$=50.002$

5. 漸變段

A.長度：採用 1.30 m

B.下游渠道起點高程：漸變段內之損失水頭不予考慮，下游渠道起點高程

$=$EI. of Energy line$-(d+h_v)$

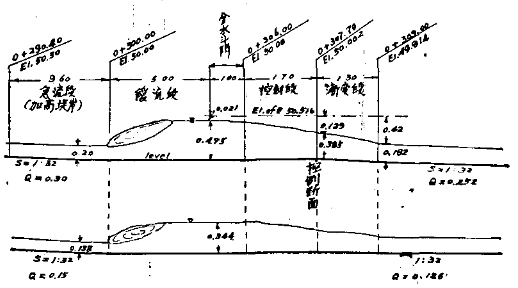
$=50.516-(0.182+0.42)=49.914$

6. 堤岸加高段長度

$$L=\frac{h}{S}$$

$h=0.90-0.60=0.30$ (m)，$S=\frac{1}{32}$

$$L=\frac{0.30}{1/32}=9.60 \text{ (m)}$$



圖四 設計間圖

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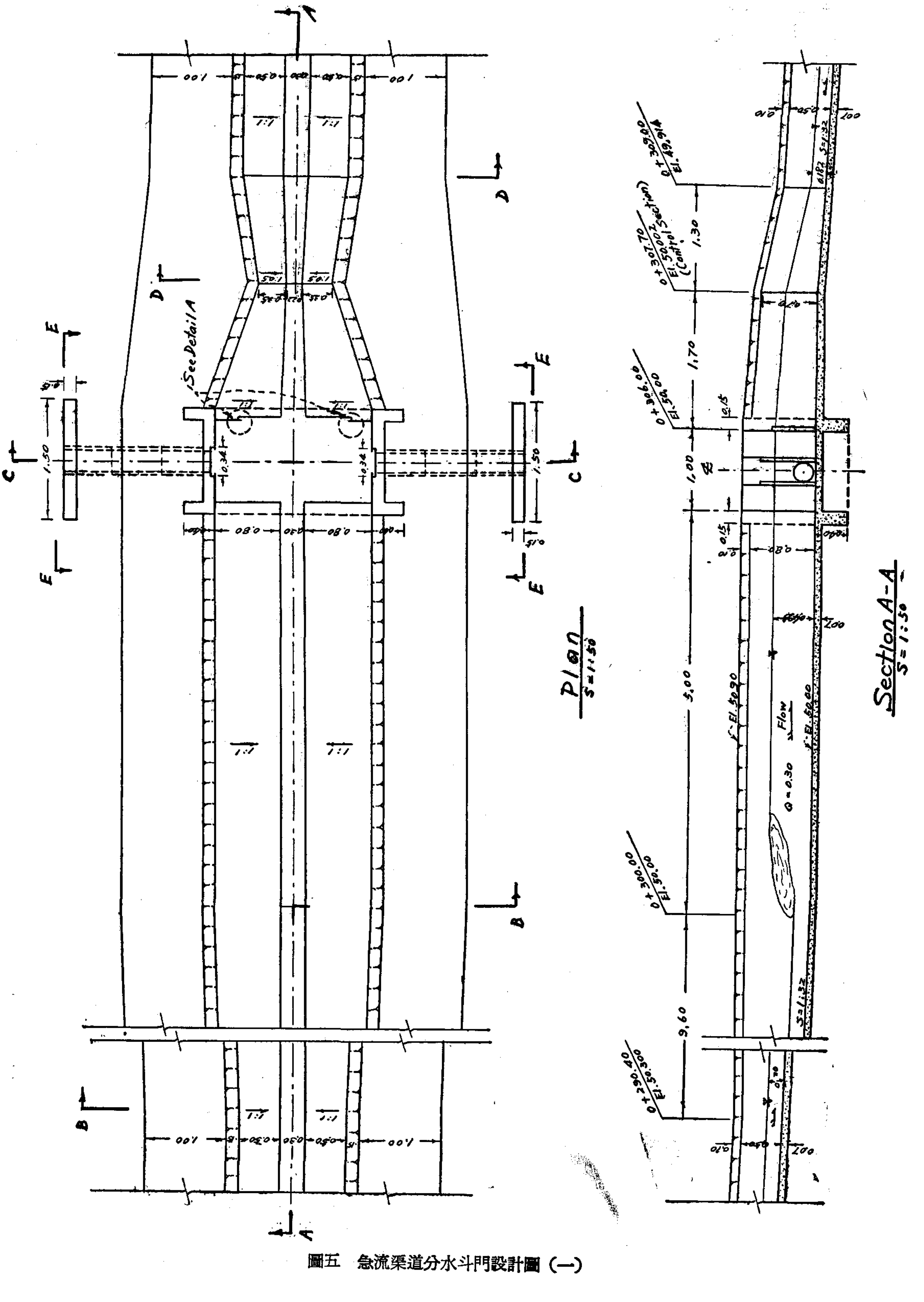
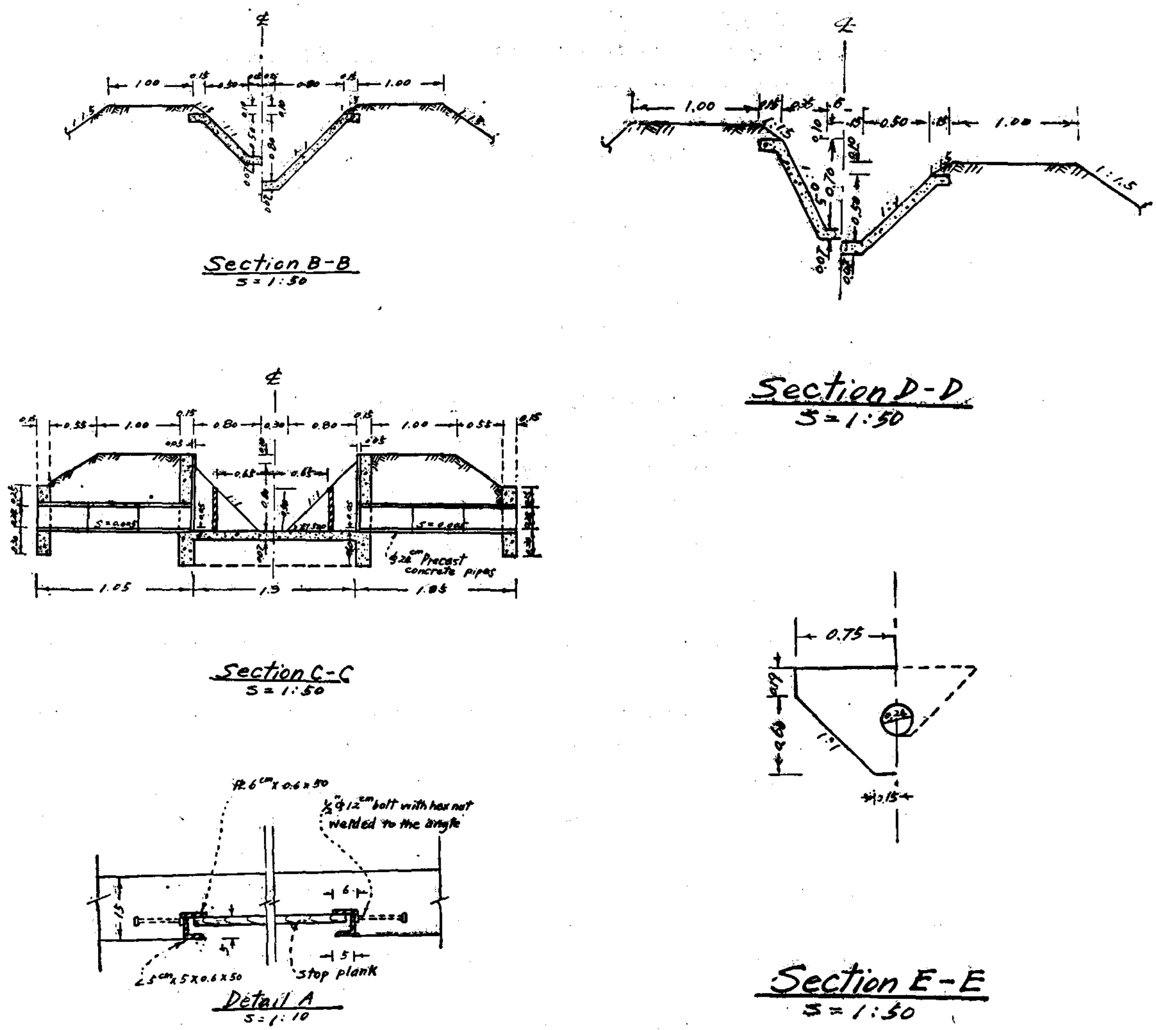


圖五　急流渠道分水斗門設計圖 (一)



圖五　急流渠道分水斗門設計圖（二）

English Summary

Turnouts are commonly used structures in irrigation channels. They divert water from a main channel to a lateral or a farm ditch. Except large structures, the smaller turnouts are usually designed to have a coveerd conduit. It is better to use check gates to control the amount of water diverted through turnouts, or the structures must be large enough and set low enough to carry the required flow from the lower water surface during the period of partial flow discharge. Generally, turnouts are located at the sections of channel with sub-critical flow. In the case of setting the structures in super-critical flow channel without any modification, the following troubles may occur:

1. It is difficult to divert water due to high velocity in main channel.

2. In Super-critical flow channel, water depth is always too shallow to divert water. If turnouts is set too low, the irrigation area will be reduced.

This paper proposes a kind of design of turnouts in super-critical flow channel.

1. In General: In this case, the turnout itself is usually the same type of structure as one in sub-critical flow channel, but the channel with steep slope is designed to have a proper distance of horizontal bottom upstream from the turnout. It is considered as a stilling pool where a hydrauic jump will be produced and super-critical flow will be changed to subcritical flow. Then, water may be easily diverted through the turnout with increased water depth and reduced velocity. In order to maintain certain water depth produced by hydraulic jump and prevent the influence of the downstream flow, a check gate or control section should be set downstream of the turnout. Now, the section of channel set with a turnout can be divided into four parts that cosist of stilling pool, turnout, control section and transition.

2. Stilling pool: A Trapezoidal cross section is adopted in this stilling pool for saving the cost of the structure. It is practicable to make the cross section the same width and side slope as the upstream channel. For the purpose of designing stilling pool and turnout, the alternative depths produced by hydraulic jump should be computed. Table 1 is provided for its computations. Figure 1 and 2 may be used as guide for determining the length and Freeboard in the stilling pool.

3. Turnout: The same type of turnouts used in sub-critical flow channel is applicable here. Its design criteria are also referred. The smaller turnout having a covered conduit may be regarded as a submerged orifice. Then, the discharge formula about submerged orifice may be used. to design the turnout.

4. Control Section: Instead of a check gate, a control section is required to control the flow and to maintain a certain depth above turnout. This control section is determined by two kinds of flow, one in full discharge and the other in partial discharge. Table 2 and Figure 3 are provided for use of the computation.

5. Transition: To connect the structure with downstream channel, transition is needed. The method of design used in other cases of structures is adopted.