

The Hydroplus Fusegate System - four years on.

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SYNOPSIS.

The Hydroplus fusegates can be utilized for increasing live storage capacity of dams with ungated spillways and/or for improving spillway safety without sacrificing storage capacity. They are designed to rotate (tilt) in succession when the reservoir level reaches predetermined elevations thereby preventing the flood from overtopping the dam. This paper discusses varying approaches in the use of the system to solve the problem of safety worldwide including the Dove Stone reservoir in the North West of England.

INTRODUCTION.

Under normal conditions fusegates increase the active storage area of reservoirs. The labyrinth weir configuration allows for increased discharge at lower heads than conventional spillways. The fusegate design allows for the fusegates to overturn during high or extreme flood events thereby allowing more flow through the spillway. These systems can increase the active storage of a reservoir and increase the discharge capacity for extreme events so that the design flood may pass without overtopping the existing dam and thus reducing or eliminating the need for increasing the dam height.

THE CONCEPT.

The Hydroplus system consists of one or more adjacent but independent fusegate units resting on the overspill sill and held in place solely by gravity forces. The fusegates are overtopped by moderate floods. In case of larger floods, some elements are overturned by rotating about lugs located at the downstream edge of the sill. The number of units activated away is graded to suit the hydrograph of the particular expected flood and match the required discharge flow.

Each unit sits freely on a concrete slab cemented into the crest and consists of three parts

- * The bucket (top part) made of steel or reinforced concrete with can be given a labyrinth shape to increase the overspill length so that moderate floods can be discharged with a relatively small head on the lip.

- * The bottom chamber base made of steel or reinforced concrete.

- * The well - a funnelled conduit into the chamber which begins to fill for a given reservoir level. Wells are set at different elevations.

The reservoir as an asset. Thomas Telford, London, 1996

When reservoir level reaches a given elevation, water flows through the well into the chamber. Pressure builds up in the bottom chamber and when sufficient vertical uplift has been mobilized, the fusegate rotates about the abutment blocks located at the downstream edge of the sill. The triggering system is very precise and leaves an ample safety margin until the reservoir level reaches the predetermined elevation activating a given element.

The fusegate on the spillway crest is acting in three different ways depending on headwater level

* As part of the dam, as long as the reservoir level does not exceed the fusegate bucket top edge

* as a weir, when headwater level is higher than the fusegate top edge but lower than the predetermined level causing the fusegate to overturn

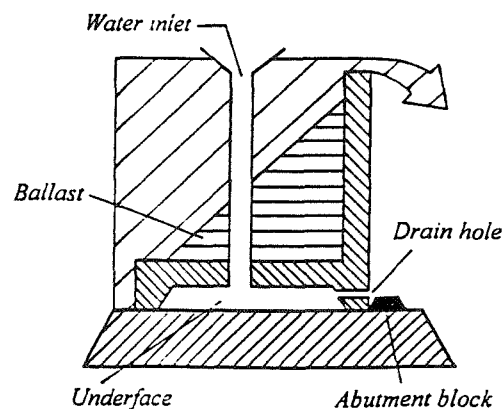
* As a "fuse" or a regular spillway gate when headwater reaches this predetermined level and triggers the uplift

Once the flood has receded, the overturned fusegate is simply lifted back on the sill or replaced with an identical new unit if seriously damaged

Extensive theoretical research has been conducted on fusegate performance when spilling and rotating and thorough model testing programs were performed to validate the mathematical approach

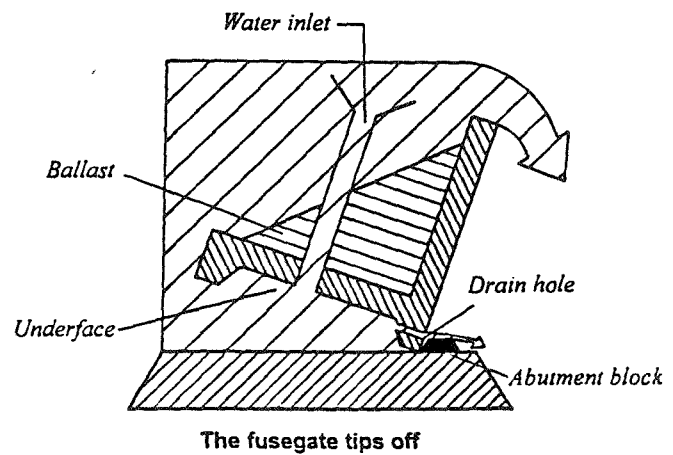
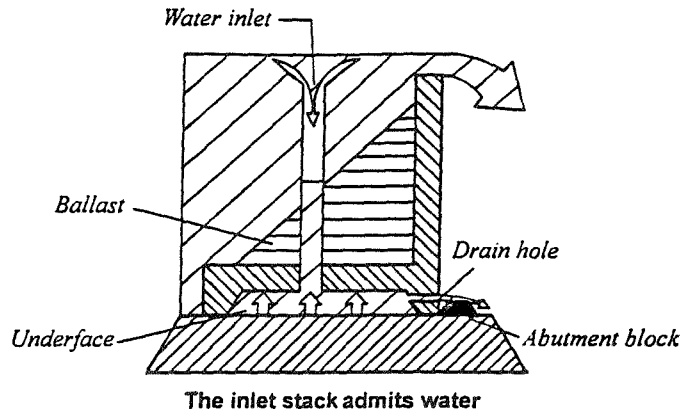
Testing of fusegates was performed at the Tennessee Valley Authority facilities at Norris (Tenn). These tests validated very precisely the behaviour of the Hydroplus fusegates under various circumstances and conditions.

Also, Ice has been the subject of specific research at the Institute for Marine Dynamics of the National Research Council, in St John's, Canada and at the Scientific Research Institute of Energy Structures, in Moscow, Russia



Water is spilling over the crest

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FUSEGATE CONFIGURATIONS.

The fusegate system may form a labyrinth or straight crest to the weir.

1 - Labyrinth Crest Fusegates

A bucket shape is used to form a labyrinth crest capable of overspilling a nappe equivalent to 30 - 150% of the fusegate height. The bucket is open at the upstream side. An alignment of buckets forms a labyrinth crest which allows moderate floods to spill with a reduced head on the crest. The developed length of the labyrinth is approximately three times that of a concrete sill length. The bucket height is commonly 1m to 6.5m, depending on the clients needs.

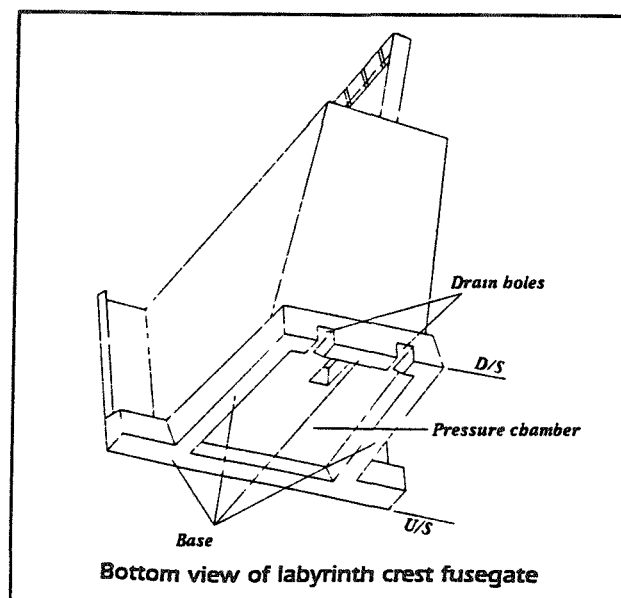
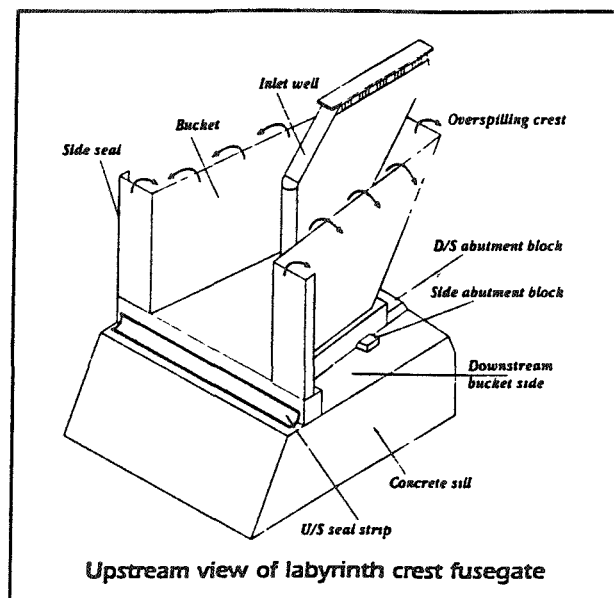
2 - Straight Crested Fusegates

There are three types of straight-crested fusegates :

Emergency Fusegates are designed to overturn before or just after being overtopped. They are used as back-up to conventional gates in the event of very large floods or gate malfunction. They may be 1m to 10m in height.

Intense Cold Environment Fusegates are designed to be very stable and their upstream face are shaped and finished to reduce ice loading, friction and abrasion.

High Heads Fusegates are designed to withstand high heads on the fusegate crest. They are constructed to obtain the best discharge coefficient and may be large (20m wide) and capable of remaining stable when spilling under a head of up four times their height



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CASE STUDIES.

Case 1.

Lussas Dam in the South-Central France provides irrigation water for agriculture on the Lussas plain. The dam is an earth construction 19.5m high. The spillway is situated on the left bank and is 36m in length.

The runoff pattern is governed by sudden, heavy storms on the relatively large catchment (26.2 km) which accounts for a large design flood. The spillway was modified and the fusegates installed in two summer months of 1991 to increase the reservoir storage capacity. The reservoir was successfully filled in time for crop irrigation soon after. During a flood in the winter of 1994 one fusegate overturned at the correct water elevation and was replaced soon after for the reservoir to fill for the next crop season.

* - New storage capacity	420,000 cubic metres
* - Sill length	35m
* - New spillway capacity	250 cubic metres per second
* - Fusegate number	10
* - Fusegate height	2.15 metres
* - Fusegate width	3.5 metres
* - Storage increase	30%
* - Spillway capacity increase	15%

Case 2.

The Wanakbori pick-up Weir in Gujarat State in India was built to collect water to irrigate two hundred thousand hectares of agricultural land. Subsequent constructions of several dams upstream resulted in higher flood control and so reduced by 2 metres the water head available at the weir. No conventional method was cost effective to restore the requested head on the 678 m long spillway.

The Hydroplus solution consisted in the installation of thirty three straight crested high overspill concrete fusegates two meter high and twenty metre long.

The first fusegate tilt for a flood of about 20 000 cubic metres per second which correspond to a 6 metres overspill over the fusegates.

* - New storage capacity	84,000,000 cubic metres
* - Sill length	675 metres
* - New spillway capacity	47,000 metres per second
* - Fusegate number	33
* - Fusegate height	2 metres
* - Fusegate width	20 metres
* - Storage increase	100%
* - Spillway capacity increase	nil

Case 3

Caillaouas Dam is at an altitude of 2,170 metres in the French Pyrenees. It is a masonry structure at the end of small but very deep natural lake. Three straight crested fusegates have been installed, to improve dam safety. A flap gate has also been installed to discharge moderate floods. The fusegates give the extra capacity to discharge the design flood. The combination of a flap gate and fusegates presents the two-fold advantage of good control of the

reservoir level. Because of the area in which the dam is located, the fusegates were transported and installed by helicopter. The operation manual for the client includes requirements for ice conditions.

* - Storage capacity	25,400,000 cubic metres
* - Sill length	7.4 metres
* - New spillway capacity	29.3 cubic metres per second
* - Fusegate number	3
* - Fusegate height	1.5 metres
* - Fusegate width	1.6 metres
* - Storage increase	nil
* - Spillway capacity increase	190%

Case 4

The Shongweni Dam is located in Kwa Zulu in Natal in the Republic of South Africa. The dam was originally built in the 1920's, the ungated spillway was 126 metres. The original design flood was rated at 1,250 cubic metres per second. After inspection in 1988 the design flood was re-evaluated at 5,000 cubic metres per second. The new safety requirements were not satisfied for two reasons. (a) the dam structure was inadequate and (b) the spillway could not discharge the re-evaluated design flood. The client examined four alternatives but settled on lowering the spillway by 8 metres. The spillway was cut back 7.9 metres and ten 6.5 metres high fusegates were installed. The result was that the reservoir level was lowered only by 1.4 metres. The first fusegate is designed to tip for a flood that occurs every 240 years. Each fusegate weight was some 120 tonnes and since the cableway safe working load was 5 tonnes the structural design had to be adapted to meet the weight limitation.

* - Storage capacity	6,600,000 cubic metres
* - Sill length	126 metres
* - New spillway capacity	5,000 cubic metres per sec
* - Fusegates number	10
* - Fusegate height	6.5 metres
* - Fusegate width	9.73 metres
* - Storage increase	nil
* - Spillway capacity increase	235%

Case 5

The McClure Dam located in New Mexico, USA is an earth structure with a maximum head of 38.6 metres and a crest length of 234 metres. The dam was built in the 1930's and raised

three times in 1936, 1947 and 1988. In 1988 the 17 metres spillway was reconstructed. With two other gravity dams, McClure supplied domestic water to the city of Santa Fe until a large crack was found in the foundation of Two Mile dam. In February 1995, the operator was allowed by the State authorities to transfer the water rights to McClure dam. In April 1995, eight steel fusegates were installed on the Ogee crested sill. The Hydroplus concept had successfully increased live reservoir storage capacity by 0.62 hm³ and spillway discharge capacity by 8 per cent.

* - Storage capacity	3,820,000 cubic metres
* - Sill length	17.3 metres

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* - New spillway capacity	507 cubic metres per sec
* - Fusegate number	8
* - Fusegate height	2.15 metres
* - Fusegate width	2.13 metres
* - Storage increase	500 acre-feet
* - Spillway capacity increase	8%

Case 6.

The Dove Stone Dam is an earth structure situated under Saddleworth Moor 8 km east of Oldham in Lancashire. Calculations and 1:21 model tests indicated that the existing bellmouth in the reservoir could pass approximately 160 cumecs. The required discharge for the PMF being approximately 300 cumecs an auxiliary spillway was required to meet safety criteria. Three fusegates were installed into the new 9.8 metre wide auxiliary spillway. The fusegates are designed to tilt off the spillway 0.53, 0.58 and 0.63 metres above the lip of each fusegate respectively. The fusegates are designed to rotate in succession between the 1 in 10,000 years flood event and the PMF thereby preventing the flood from overtopping the dam.

* - Storage capacity	5,050,000 cubic metres
* - Sill length	9.8 metres
* - New spillway capacity	282 cubic metres per sec
* - Fusegate number	3
* - Fusegate Height	2.15 metres
* - Fusegate width	3.23 metres
* - Storage increase	Nil
* - Spillway capacity increase	42%

CONCLUSION.

Hydroplus Fusegate systems are being used Worldwide including the United Kingdom, China, South America, United States of America, parts of Africa and South East Asia and areas of Europe. The system has proved and established its versatility in application, in the use of materials, methods of construction and logistics.

The Hydroplus Fusegate system is a method by which dam safety and/or storage capacity can be achieved in a cost effective manner.

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