Key Issue: **5 - Water Quality**
2-Hydrogical Regimes

Climate Zone:
Cf : Temperate humid climate

Subjects:
- Implementation of measures to solve turbid and cold water problems at dams and power plant intake gates and discharge for the ecological flow

Effects:
- Improvement of the river environment

Project Name: Kobo Dam
Country: Hiroshima Prefecture, Japan (Asia)

Implementing Party & Project
- Project: The CHUGOKU ELECTRIC POWER CO., INC.
1945 (Completion of construction) -
- Good Practice: The CHUGOKU ELECTRIC POWER CO., INC.
Measures to treat cold and turbid water:
1998 (Commencement of operation) -
Discharge for the ecological flow:
2000 (Commencement of operation) -

Key Words:
Ecological flow, simple surface intake, measures to treat cold and turbid water

Abstract:
With growing public interest in the natural environment, more emphasis is on the river environment at hydroelectric power plants. With this social background, the Kobo Dam of the Kannose Power Plant solved the turbid and cold water problems by constructing a simple surface intake using turbidity-preventing membrane. Moreover, to discharge the ecological flow, an outlet was constructed by boring the dam body.

1. Outline of the Project

The Kannose Power Plant uses, as the reservoir, the Kobo Dam (a concrete gravity dam with the 3rd largest storage capacity among dams operated by Chugoku Electric Power) constructed in the Kannose River, which belongs to the Gounokawa River system. This dam and conduit type power plant began operating in 1945. Table-1 shows the specification of the Kannose Power Plant and Fig.-1 shows the location map.

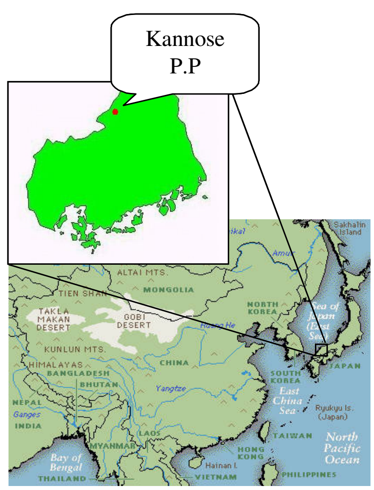

Fig.-1 Location Map of the Kannose Power Plant

Table-1 Specifications of the Kannose Power Plant

Power Plant	Maximum output	20,000 kW
	Maximum discharge	20 m^3/s
	Effective head	121.08 m
Dam	Name	Kobo Dam
	Type	Concrete gravity
	Height	69.40 m
	Crest length	195.70 m
	Catchment area	156.7 km^2
Reservoir	Total storage capacity	39,658,000 m^3
	Effective storage capacity	35,858,000 m^3
	Available depth	33.20 m
Conduit	Length	3,475 m
	Cross section	ϕ 3.3 m

The Kannosegawa River system has three power plants, the Kannose Power Plant located most upstream, Kimita Power Plant and Moribara Power Plant, developed under effective serial projects. The water released for power generation from the upstream power plant is directly led to the conduits of the downstream power plant, and this has caused reduced water flow along a river section of a total of 36 km (See Fig.-2). The Kannose Power Plant had suffered from problems associated with turbid water persistence resulting from lumbering in the nearby mountains and with cold water discharge resulting from the use of the deep layer intake method. Countermeasures were therefore taken that included the construction of a surface intake in 1997 and the construction of an outlet to discharge the ecological flow in 2000.

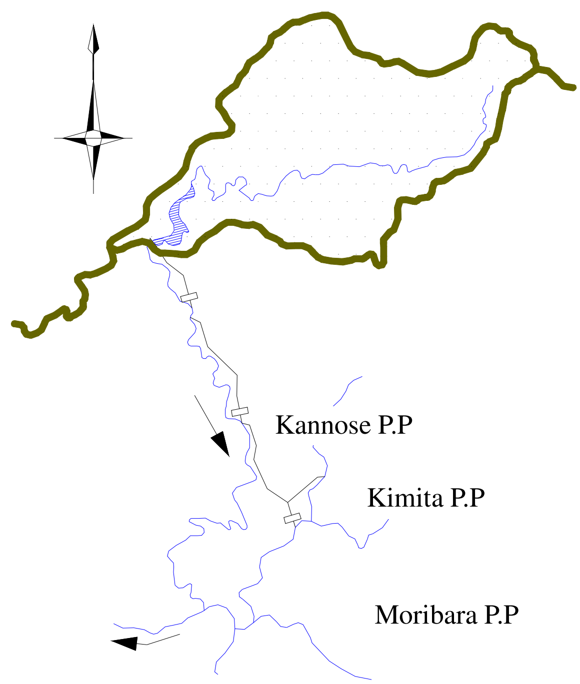

Fig.-2 Power Plants in the Kannosegawa River System

2. Features of the Project Area

The Kobo Dam is located in the upstream section of the Kannose River, which belongs to the Gonokawa River system originating in the Chugoku Mountains, and the dam lake is surrounded by mountains in the range of 700 m on both banks. The mountain slopes around the reservoir are steep, between 40 and 50 degrees, and dotted with flat areas with a layer of accumulated volcanic ash. Natural forests of Japanese beeches and Japanese blue beeches are partially found in the mountain tops in the catchment area, but artificial forests of needle-leaf trees such as the Japanese cedar and cypress cover a large part of the catchment area, creating a broad forest zone. The catchment area is characterized as a cold region with an average annual rainfall of approx. 2,000 mm and a large snow accumulation in winter that causes a temperature drop down to -10℃.

Since the area around the dam has outstanding natural landscapes and precious natural environments remaining largely intact, it was designated as a prefectural natural park in 1998. The downstream area of the dam, in particular, forms a steep, V-shaped valley approx. 300 m deep, created by erosion by the Kannosegawa River, and massive rocks, strangely shaped rocks, cliffs as well as extraordinary natural phenomena such as the welling up of mineral water springs can be seen here. The area, also blessed with a rich natural environment, has ideal spots for camping, fishing, hiking and other outdoor activities throughout the year.

3. Major Impacts

3.1 Turbid and cold water problems

The Kobo Dam had an inflow of sediment into its reservoir due to turbid streams caused by lumbering in nearby mountains every time flooding occurred. Since the sediment is made of fine trass, it is slow to settle and caused turbid water persistence in the reservoir. The use of the deep layer intake method for water intake for power generation, on the other hand, was inevitably accompanied by the discharge of low temperature water flowing in the bottom of the lake to the downstream river reach from the outlet of the power plant.

3.2 Ecological flow

When the Kannose Power Plant began operating in 1945, no discharge was initially done for the ecological flow immediately downstream of the dam. However, when the water rights were renewed for the first time, the adoption of measures to discharge the ecological flow was made.

4. Mitigation Measures

4.1 Turbid and cold water problems

To obtain base data for measures to solve turbid and cold water problems, turbidity and water temperature have been measured every day since 1990 at a number of points in river reaches upstream of the reservoir, within the reservoir and in river reaches downstream of the outlet of the power plant.

The reservoir turnover rate (Table-2) produced from the sorting and analysis of measured data to identify the characteristics of the reservoir suggests that the reservoir is of a stably stratified type. The changes in turbidity following flooding (see Fig.-3) indicate that although turbidity quickly decreases in the surface layer, turbid water is left stagnating in the intermediate and bottom layers (Intake) for a longer period than in the surface layer. These data indicate that the reservoir has the characteristics of a stratified type reservoir. The data also indicate a large difference in the number of days needed for water clearance (the number of days needed before the turbidity is reduced to 10 ppm or lower): three days in the surface layer and 15 days in the bottom layer (Intake), though varying depending on the scale of flooding.

Table-2 Reservoir Turnover Rate

<table>
<tr><td rowspan="3">Annual turnover rate (α) *1</td><td>1993</td><td>9.1</td><td rowspan="3">*1
Annual turnover rate = Annual amount of water inflow into the reservoir / Total storage capacity of the reservoir
α < 10 : Stably layered type
α > 20 : Mixed type</td></tr>
<tr><td>1994</td><td>4.0</td></tr>
<tr><td>1995</td><td>6.4</td></tr>
<tr><td rowspan="3">Reservoir turnover rate by flooding (β) *2</td><td>β < 0.5</td><td>0 times</td><td rowspan="3">Number of flooding incidents between 1993 and 1995: 4 times
*2
Reservoir turnover rate by flooding = Total amount of water inflow during flooding / Total storage capacity of the reservoir
β < 0.5 : No changes in the water temperature distribution
0.5 ≤ β < 1 : Slight changes in the water temperature distribution
β ≥ 1 : Changes in the water temperature distribution</td></tr>
<tr><td>0.5 ≤ β < 1</td><td>4 times</td></tr>
<tr><td>β ≥ 1</td><td>0 times</td></tr>
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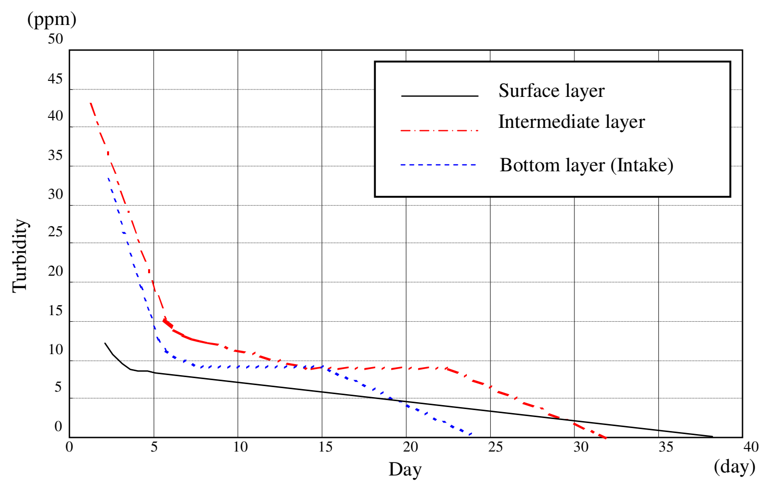

Fig.-3 Changes in Turbidity following Flooding

Water quality (which is expressed by indices such as BOD, COD, T-N and T-P) in the reservoir has been investigated about once in every three years since 1978. A comparison of reservoir water quality against the water quality criteria for Type A Rivers* specified by the environmental standards indicates that all quality indices with an exception of coliform bacteria number have satisfactorily met the criteria and that water quality has remained generally unchanged over time. With regard to eutrophication in the reservoir, the trophic level in the reservoir has remained intermediate with no signs of increasing eutrophication.

* Type A Rivers: The second highest level of 6-class environmental quality for the conservation of the living environment in rivers in Japan.

Based on the result of the investigation, it was considered effective to construct a surface intake as a countermeasure for turbid and cold water. However, the installation of a mechanical, selective intake in the intake gate was estimated to require the construction cost of up to several billion yen and the generation of a large amount of waste energy. This therefore necessitated the examination of feasible, low-cost countermeasures to guarantee adequate performance.
The Tateiwa Dam of the Uchinashi Power Plant run by Chugoku Electric Power had faced similar turbid and cold water problems. However, a simple surface intake using silt protector installed in the dam in 1995 proved to improve the problems. This prompted a decision to install a similar facility at the discussed site, and this was followed by detailed examination based on the data of the Tateiwa Dam. The model for the facility is shown in Fig.-4.

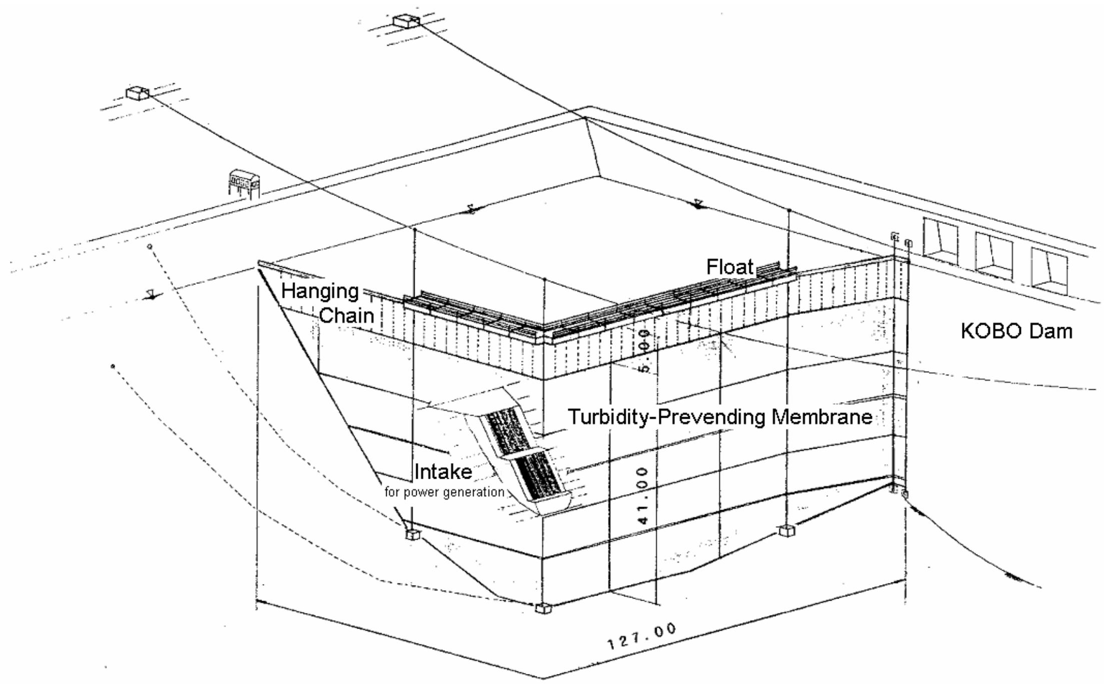

Fig.-4 Simple Surface Intake Model

The turbidity, water temperature and flow speed data measured at the surface intake with an intake depth of 7 m installed in the Tateiwa Dam were first sorted and analyzed to examine the effect of the surface intake. The result of the analysis confirmed that water up to 8 m deep primarily entered the simple surface intake, and the intake of water closer to the surface was considered more effective in reducing turbidity because the turbidity in the reservoir decreased most quickly in the surface layer. Next, an optimum depth of surface water intake that guarantees a greater turbidity reducing effect as well as ensures facility strength and safety was examined, and as a result, it became clear that at the intake depth of only between 3 m and 5 m, the outlet guarantees an optimum turbidity reducing effect. Finally, considering the larger amount of water intake in the Kobo Dam than in the Tateiwa Dam, the depth of surface water intake was set to 5 m. Table-3 and Fig.-5 shows the general information about the facility installed in the Kobo Dam.

Table-3 Specifications of the Surface Intake

Structure	Open-top type pollution prevention membrane	
Length	127.0 m	
Height of the opening	5 m	
Float	* Framed steel float (with styrene foam) 3.05 m wide×70 m long	
	* Float 600 mm diameter×57 m long	
Turbidity - Preventing membrane	Area	4,160 m^2
	Membrane thickness and material	0.9 mm Polyester synthetic fiber

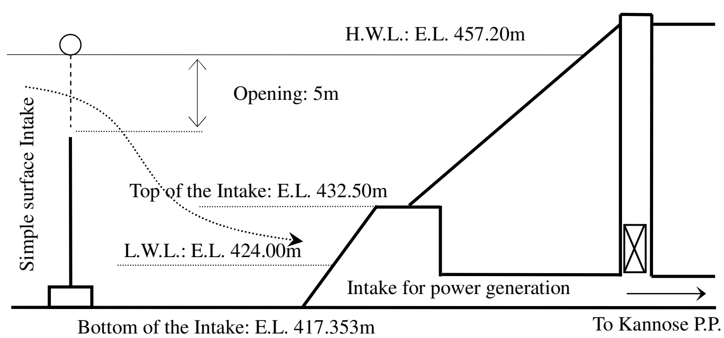

Fig.-5 Locational Relationship between the Intake Gate and the Surface Intake in the Kobo Reservoir

4.2 Ecological flow

To determine the ecological flow regime, a prior investigation of the river environment was conducted along the 7 km section with reduced water flow of the Kannose Power Plant, and this was followed by the investigation and analysis of the current conditions regarding ten items (including the protection of the local fishing industry, landscapes and animals and plants, and the maintenance of clean water flow) specified in Article 10 of the Enforcement Ordinance of the River Law to examine the required outflow discharge (See Table-4).

Through the discussion and coordination with river administrators and other concerned partied based on the result of the examination, the discharge of 0.47 m3/s was determined. Moreover, with the attendance of river administrators and concerned local parties, a discharge test was conducted to examine and assess the water depth, water surface width and other factors.

The outflow discharge test proved that the outflow discharge increased the water surface width and the seeming abundance of water when viewed from afar, and thus improved river landscapes.

Local parties concerned also expressed opinions in favor of our outflow discharge plan.

Table-4 Assessment Items (Principal Items)

Assessment Item	Current Condition	Concept behind the required outflow discharge
Fishing industry	① River sections to which no fishing rights are attached ② Inhabiting fish species Investigation by literature study, interviews and on-site fish catching Sweetfish, big-scaled redfin, White spotted Char, a kind of loach (*Cobitis takatsuensis Mizuno*), spotear brook perch and other species	* Maintenance of water depth over the shoal (for sweetfish) * Water quality: Water quality that meets the criteria for Type A Rivers (the environment suited for the habitation of stream fish species such as the big-scaled redfin and Japanese char)
Landscape	Largely located in an area designated as a prefectural natural park Camping sites are present	Flow rates that guarantee visual satisfaction (Flow rates at which the increase is only slightly reflected in the width of water surface.)
Protection of animals and plants	* Fish species: The species listed in the fishing industry column were found. * Plants: No aquatic plants designated as rare species are present.	* Fish species: The concept shown in the fishing industry column applies. * Plants: Excluded from the target
Maintenance of clean water flow (Regulatory environmental criteria for BOD)	0.4 ppm in downstream reaches of the Kannose Valley	Maintenance of water quality (a BOD of 2 ppm) that meets the specified criteria for Type A Rivers in normal times

Before water discharge After water discharge

Fig.-6 Photo showing the outflow discharge test

The inlet to discharge the ecological flow was constructed in the above mentioned surface intake by boring the dam body. The specifications and a sketch of the facility are shown in Table-6 and Fig.-5, respectively.

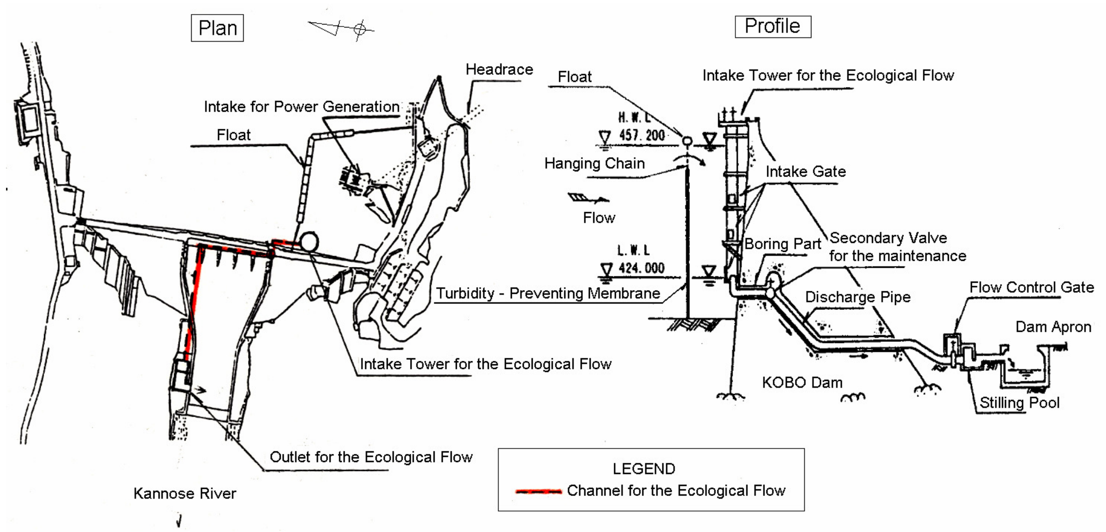

Fig.-7 A Sketch of the Facility

Table-5 Specifications of the Facility for the Ecological Flow

Intake tower	Porous steel intake tower [Pipe diameter: 800 mm, Tower height: 38 m]
Intake gate	Steel slide gate [Dimensions: 640 mm x 630 mm Number of gates: 3]
Outlet conduit	Weld steel pipe (flange joint) [Dimension: 400 mm Length: 147 m]
Outlet control gate	Steel high pressure slide gate [Dimensions: 400 mm x 400 mm Number of gates: 1]
Energy dissipation tank	Impact energy dissipation tank [2.0 m wide x 4.0 m long]

5. Results of the Mitigation Measures

To determine the effect of the surface intake at the Kobo Dam and the present condition of the downward flow of turbid water, the turbidity, water temperature and other parameters were investigated after flooding (See Table-6).

The investigation confirmed that the water flow was faster at the depth of 2 m and 4 m where an opening is located than at other water depths and that the flow was running toward the intake gate.

A comparison of water temperature and turbidity in the Kobo Reservoir and at the outlet of the Kannose Power Plant revealed that these parameter values measured at the depth of 4 to 6 m in the reservoir were much the same as those measured at the outlet. This, therefore, confirmed that the facility installed for the purpose of clean surface water intake was properly fulfilling its function and helping to improve turbid and cold water problems at the outlet.

It was also confirmed that the discharge for the ecological flow improved the animal and plant habitats and river landscapes. The local government, which regards the catchment area of the Kannose River as the center of tourism and water activities, is moving ahead with the construction of facilities.
Particularly in the last few years, summer events (such as hand catching of fish, and riding on a raft and log) have attracted a growing number of visitors to the camping site.

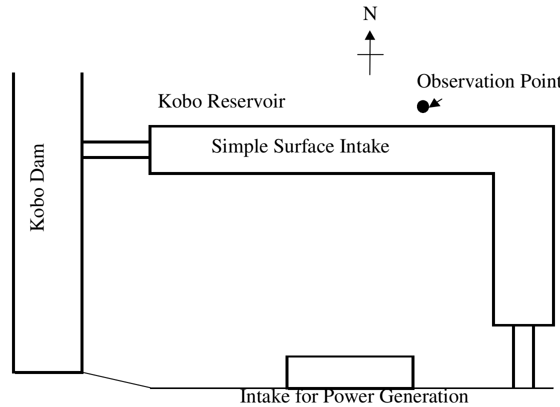

Table-6 Result of Investigation of the Turbidity, Water Temperature and Other Parameters (1998.10)

		Observation point	Water temperature (℃)	Turbidity (ppm)	Flow rate (cm/s)	Flow direction (°)
Inside the reservoir (outside the surface	Opening	Surface	17.0	2.4	0.7	9
		Water depth 2m	16.7	2.5	3.9	234
		Water depth 4m	16.3	12.2	5.5	188
	Pollution prevention membrane	Water depth 6m	16.1	35.6	1.3	112
		Water depth 8m	16.0	51.8	1.2	204
		Water depth 10m	15.9	48.0	3.1	174
		Water depth 12m	15.9	47.5	1.3	218
		Water depth 14m	15.8	38.4	1.8	279
		Water depth 16m	5.8	54.5	3.2	196
Outlet of the Kannose Power Plant			16.4	25.4	-	-

* A clockwise direction was used with the north equating to 0 degrees
(The direction of the intake gate is about 180 degrees.)

6. Reasons for Success

The following factors are considered to have contributed to the success of the project.

1) Discussion and coordination with river administrators and other concerned parties and implementation of the outflow discharge test
The ecological flow regime was determined through discussions and coordination with river administrators and other concerned parties based on the investigation and examination to protect landscapes, animals and plants. The on-site outflow discharge test conducted with the attendance of river administrators and local residents to visually examine the effect was met with favorable opinions from local parties concerned.

2) Detailed investigation, analysis and examination in the planning and design stages

a) The surface intake in the Kobo Dam, which was constructed after the method using pollution prevention membrane earlier adopted in the Tateiwa Dam of Chugoku Electric Power, was able to yield an increased water improvement effect, thanks to the improvements added.

b) The construction of the facility of the ecological flow, which involved boring through the dam of about 70 m high to install the facility, was preceded by the examination of the effect of the construction on the dam using the FEM analysis (to determine the conditions of the bored sections before, during and after the construction, and local compressive and tensile stress around the inspection gallery) and the confirmation of the absence of structural problems.

c) Structures and construction methods that can produce substantial effects at relatively low cost could be adopted for both facilities.

7. Further Information

7.1 References

Shinya Nakagawa, Yutaka Sasaki and Kouji Yoshimura: "Design and Construction of the Outlet to Maintain the Ecological Flow at the Kobo Dam of the Kannose Power Plant", Japan Electric Power Civil Engineering Association, No. 286, March 2000

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