IoT-BASED SMART DAM SYSTEM USING STM32F103C8T6 ARM CORTEX AND ESP8266

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***Abstract*—Maintaining the water level in a dam is really important. The water level in the dam affects the amount of potential energy present to generate electricity, higher water level gives high potential energy. Also, the water level should not rise above the crest of the dam as it increases the risk of bursting the dam and causing major floods in nearby villages and cities. To overcome this problem, we have created a smart dam system using RS-485 serial communication protocol between a single-chip embedded controller ARM cortex STM32F103C8T6 and ESP8266. The water level will be measured using a capacitive sensor connected with STM32. STM32F acts as the master and serially communicates with ESP8266. Servo motor and Infrared sensors will be connected with ESP8266 to open the floodgate and detect the obstacle near the floodgate. The floodgate will be opened automatically based on the water level. The water level and status of the floodgate will be updated lively in a website that we created and a notification will be sent to the locals in case of any emergency due to the water level using IFTTT.**

Keywords— STM32F103C8T6, ESP8266, RS-485, Water level sensor, Servo motor, Infrared Sensor, Website Development, IFTTT.

I. INTRODUCTION

Countries across the world are actively searching for ways to efficiently utilize their share of freshwater resources available in their country. And as the global population increases the demand for freshwater supply will grow proportionally too. So, the need for managing water efficiently and utilizing it to its full potential has become a matter of sustainability and survival. Even in India because of the extensive cultivation of water-intensive crops, the freshwater resources are depleting, especially the groundwater. So the water requirements in the future are probably met by flowing water and desalination plants. To make sure the flowing water in the rivers is used sustainably and efficiently we need a smart dam system. Unlike the earlier times now we need to make sure we meet the downstream demands alongside conserving water and minimizing usage. The real-time data the smart dam system provides helps us to efficiently manage water and optimize water release and flow. The changing climatic conditions make it difficult for human beings to make timely adjustments to avoid any mishaps and this is where automation by smart dam systems comes in handy. This smart dam system also helps in improving safety by monitoring dating in a real-time and giving timely updates. The data it provides also helps with the proper maintenance of the smart dam and helps in reducing costs in the long run. In the modern world with the number of technological advancements that humanity has seen we must start focusing on environmental sustainability too. The smart dam helps in reducing all the environmental impacts that traditional dam systems might ignore. Smart dam systems will prove to be a game-changer for water management in the near future.

II. LITERATURE REVIEW

An IoT-based [1] monitoring system that has been deployed to control the level of water in the dams and automatically sends flood water to the canal. The measure of water is sent to the controller and controller controls the reservoir gates based on the sensor data received. This paper [2] focuses on developing an effective flood detection and alert system. Machine learning (ML) is used to monitor the behavior of machines and detect abnormal patterns.[3] IoT-based flood detection and warning system designed to monitor water levels in three different areas and detect any changes. Usage of IoT and several protocols like XMPP for reservoir safety monitoring in hydroelectric

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power stations are discussed in [4]. Real-time communication is achieved devices and Supervisory Control and Data Acquisition (SCADA) systems through an IoT based system that is designed. The paper [5] proposes the development of information to collect and share real-time information about water levels with a central command center to control gates. An IoT system for real-time control and monitoring of water level is created in the paper [6]. The system control sluice gates with three water level conditions. The web server interface provides real-time data and the system shows a 0% percentage error and a 2-second time delay in sending data. A Water Level Management system that monitors and controls water levels in dams and reservoirs is created in the paper [7]. The system provides real-time monitoring and management using a web server as an interface. Paper [8] proposes an IoT device that monitors water levels and automatically switches off the motor when water levels are too high or too low. The device also measures the pH level of the water and sends all the information to the user via SMS. A dam water management system with IoT application that uses advanced sensor networks to monitor and manage water levels in dams is presented in [9]. The project aims to prevent flooding and is designed to aid agriculture by calculating the amount of water needed for different crops. The author [10] discusses a water level management system using RF communication technology, the system is designed to monitor water levels in reserve and roof tanks and control water pumps automatically to minimize water waste, save power, and reduce human involvement. The project implements a flood monitoring and detecting system to address the severe flood disaster affecting India. The proposed IoT based system can sense a rise in water level, allowing engineers to decide to counter the situation is discussed in [11]. The severity of flood is recorded in ThingSpeak as a graph.

The investigation is done between two real-time flood monitoring frameworks utilizing wireless data transmission systems, the GSM SIM900A module and the XBee Pro module, for monitoring purposes in sub-urban areas. Both systems are effective in providing warnings immediately in real-time, with XBee Pro being used for the areas with good internet access and the GSM module is used if internet service is limited is proved in the paper [12]. The paper [13] proposes a reservoir management system for Indian water reservoirs to measure certain parameters. Pressure and water level are some of the parameters that are measured. The data is transmitted to Microsoft Power BI, where it is visualized, and alarms are triggered for emergency water level increases. The aim of the author of the paper [14] is to introduce an IoT device that monitors water levels, switches the motor on when the water level goes high and switches off if it goes below a certain point, and information about pH level of water is also provided. The device is SMS-enabled and forwards all the gathered information to the user through an SMS. The importance of monitoring heater water levels in industrial alarm systems of thermal power plants is mentioned in the paper [15]. Multiple factors have been proposed that affect heater water levels and performing root cause analysis for corresponding alarms is discussed, causes of alarms based on the heater types (high pressure and low pressure) have been discussed. The study [16] presents a simple and low-cost IoT-based water level monitoring system using sensors and automatic switches, and the Blynk application is used to detect water levels autonomously.

III. Hardware Components Used

A. *STM32F103C8T6 Arm Cortex M3 MCU*

The STM 32 is a family of 32-bit microcontrollers designed and produced by STMicroelectronics. The STM 32 family is based on the ARM Cortex-M processor architecture and is one of the most popular families of microcontrollers used in embedded systems and IoT. STMicroelectronics provides a comprehensive software ecosystem for the STM32 microcontrollers, including development tools, and software libraries. STM32 has analog and digital I/O pins and its configuration is typically done through a tool such as the STM32CubeMX or directly through code. The ports are mentioned in the alphabet and pins are identified by a number.

B. *ESP8266 Node MCU*

The NodeMCU is an open-source firmware and development kit based on an ESP8266 microcontroller. It includes hardware that is formed on the ESP12 module and firmware running on ESP8266 WiFi Soc from Espressif Systems. It’s built on top of the Lua programming language. It includes a Wifi module, which allows it to connect to the internet and communicate with other devices over a wireless network. It also has a USB port for programming and debugging and eleven GPIO pins along with RX and TX for connecting to sensors actuators and other electronic components. It also supports several communication interfaces such as 12C, SPI, and UART.

C. *RS-485*

RS485 is a standard for serial communication that is commonly used in industrial control systems, building automation systems, and other applications that require reliable long-distance communication. It is designed for half-duplex communication. It supports multiple devices on the same bus, with each device having a unique address. This allows multiple devices to communicate with each other over the same network. The standard also supports multi-drop configuration, which means that multiple devices can be connected to the same pair of wires. It can reliably transmit data up to 1200 meters at speeds of up to 100kbps, depending on cable quality, the number of devices, and other factors.

D. *Water Level Depth Sensor*

A water level depth sensor using capacitive sensors is composed of ten traces made of copper, among which five of them will be power traces and the other five are sense

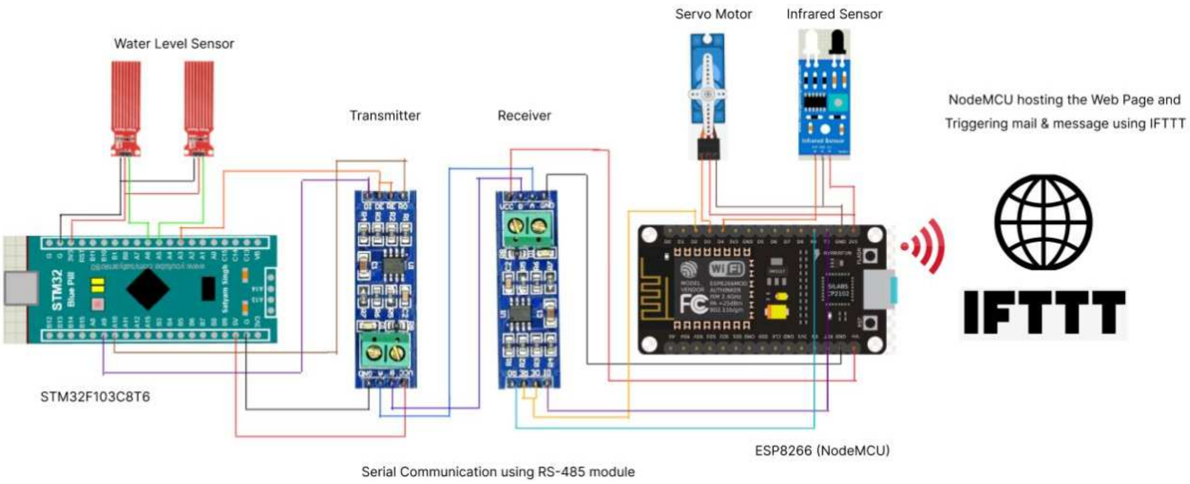

Fig. 1. Schematic Diagram of Smart Dam System

traces. Sense traces and power traces are arranged alternatively. When dipped in water, the power and sense traces are connected, forming a variable resistor whose resistance changes, similar to a potentiometer. The generated voltage from the sensor varies directly according to the resistance. We can measure the water level based on the produced voltage.

E. Infrared Sensor

An infrared sensor is optoelectronic and radiation sensitive having spectral sensitivity in the wavelength range of 780nm to 50 µm. In our project, we are using an IR sensor for obstacle detection. The sensor gathers heat radiation which shifts in time and space as a result of obstacle movement in the dam within a specified range. This sensor will be kept near the flood gate to detect the obstacle and alert the authorities.

F. Servo Motor

The Servo motor is a rotary actuator. The Servo motor has a feedback mechanism, a motor, and a control circuit. It is designed to provide accurate control of movement and position, making them ideal for applications where precision is important. In our project, we use it as the gate for our reservoir.

IV. Software Used

A. IFTTT

If This Then That (IFTTT) is a website which allows its clients to create applets, which are simple programs that automate tasks between two or more web-based services. The service connects with over 600 services, including social media platforms, smart home devices, email services, and more. An IFTTT applet consists of a trigger and an action. The trigger is the “if this” part of the equation, and it is what initiates the applet. The trigger can be an event that occurs on a connected service. Users can also create more complex applets by customization.

B. Website Development

ESP8266 is a Wi-Fi module with NodeMCU firmware. This function as a microcontroller and connects the module to the internet. Here we use NodeMCU as a web server in its station mode. The code will scan for the incoming request, this will be sent by the sensors connected with NodeMCU (water level and IR sensor). The input will be received and the server will parse the request and send a response. This code is created using C, HTML, and CSS. The NodeMCU’ s IP address will be used to open and access the webpage. The webpage consists of a gauge to show the water level and it also lively updates the status of flood gates and obstacles.

V. Advantages Of STM32 Over AVR Processor

The Bluepill microcontroller (STM32F103C8T6) has a more powerful ARM Cortex-M3 processor (32bit,72Mhz), compared to the AVR processor (8bit,16MHz) on the Arduino Uno and has better memory (128 KB flash memory and 20 KB SRAM). The number of pins is more in the blue pill microcontroller, compared to Arduino Uno and Bluepill is cheaper. This makes the blue pill microcontroller (STM32F103C8T6) a better choice for more complex projects that require more processing power and memory, compared to Arduino Uno. STM32 microcontrollers are known for their high-level integration, scalability, efficient performance, and minimal power consumption. They offer a wide range of peripherals, including digital to analog converters, timers, communication interfaces, and various other features required for building complex embedded systems.

VI. Methodology

The smart dam system uses the RS-485 communication protocol for serial communication. RS-485 has a data rate of 30Mbps and a range of 1.2km which makes it suitable for real-life dam applications. Up to 32 devices can be connected using this protocol. We are connecting STM32F with ESP8266 using two RS-485 modules, one will be connected with STM32 other will be connected with ESP8266. STM32F will act as the master. The transmitter and receiver of the STM32F and ESP8266 will be connected with RS-485 to enable a serial communication path between them.STM32F reads the water level from the capacitive water level sensor and transmits the data serially. The transmitted data will be passed through the RS-485 module and be received by ESP8266.

As shown in Fig.1. The Servo motor and infrared sensor are connected to ESP8266. Based on the data (Water level) received from STM32F, ESP8266 will control the servo motor and infrared sensor. There are five levels, fully closed, 25% opened, 50% opened, 90% opened, and fully opened, according to the water level, the Servo motor will open the floodgate. An infrared sensor is used to detect the obstacle near the floodgate. Since this is a miniature version of the dam, we are using an Infrared sensor. In real-life applications, a camera with a machine-learning algorithm can be used to detect obstacles near the floodgate. If an obstacle like a human or any living being is detected near the floodgate, a warning will be sent and the floodgate will not be opened. As soon as the obstacle is moved, floodgates start functioning normally.

ESP8266 receives the data serially and controls the floodgate and detects the obstacle. ESP8266 can access Wi-Fi, which can be used to host a website and send mail and messages. So, using HTML and CSS we created a website to check the status of the dam lively. The level of water in the dam, obstacles detected, also how much the floodgate is opened can be seen on the website. All this information will be lively updated using ESP8266. Additionally, a mail and message will be sent to the registered user in case of any emergency like dam overflow or sudden opening of flood gates.

This website will be useful to the locals nearby because they can check the water level regularly and be safe during heavy rains and other worst-case scenarios where other nearby dam's waters are directed towards this dam and floodgates needed to be opened, increasing the water level in the river.

VII. Working

Two RS-485 module is used for half-duplex serial communication between the master (STM32) and slave (ESP8266). One RS-485 will act as a transmitter and the other will be the receiver. STM32 will send the data in form of an electrical signal, which will be converted to a digital signal. The signal will be sent in a form of a differential signal to the receiver. The receiver decodes the data and sends it to ESP8266. In this way, serial communication will happen between STM32 and ESP8266. The capacitive sensors connected to the STM32 detect the water level and transmit it serially to the ESP8266.

$$P = \rho . g . H + P_0 \tag{1}$$

In equation (1), P denotes the pressure of the liquid surface, the acceleration of gravity denotes by g, ρ denotes the density of the liquid, and Atmospheric pressure denoted by "Po" and depth is by "H". Using this formula, the water level will be calculated.
ESP8266 will control the servo motor and Infrared sensor based on the input received from the water level sensors. The servo motor uses the principle of Pulse width modulation (PWM).

$$W = D \times F \tag{2}$$

In equation (2), "W" is work, "D" is distance, and "F" is the force of rotation. In a servo motor, for the applied work, the force will be high and the distance will be less.

Now, the NodeMCU (ESP8266) will be connected to a router's Wi-Fi network using its password and SSID. A local IP address will be generated for ESP8266 after connecting. We are using the station mode of ESP8266 to host a web server. Using the generated IP address, we can host a webserver by pasting the link on any browser. Using the same IP address other clients can also view the webpage created. In the created website, the water level of the dam, the status of the floodgate, and whether an obstacle is present or not will be displayed and updated lively. The background color of the website will also be changed according to the water level and emergency.

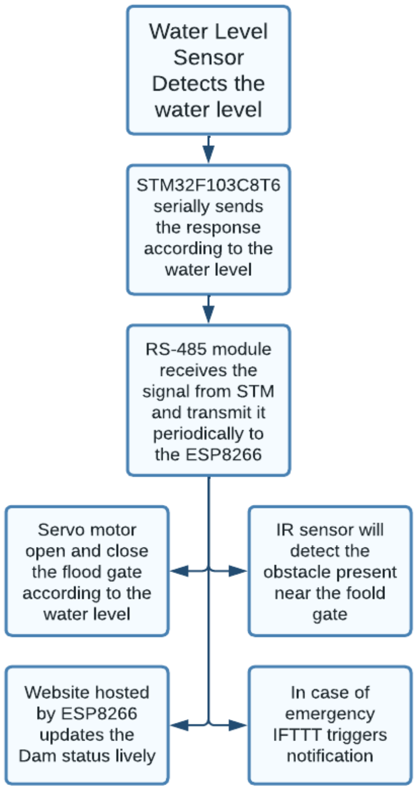

Fig. 2. Work Flow Diagram

A message and mail will be sent to the registered locals using IFTTT (If This Then That). IFTTT works in the principle of receiving an event's output as a request and if that event occurred, then this (any event) event will be triggered. The ESP8266 will act as a client and POST a request using HTTP (Hypertext Transfer Protocol). We used the Webhooks applet to receive the web request from ESP8266 and send a mail using the "Email" applet as a response. The "Message" applet is used to send messages to the registered mobile number in the same way. Like the work flow is shown in Fig.2., our smart dam system works automatically and updates the dam status in a website lively and send notification in case of emergency.

VIII. Results and Discussions

As shown in the schematic figure, connections are made. In Fig.3., We used a 15x20cm PCB board to construct and soldered the circuit. Connections are made as shown in the schematic diagram. Here we have a miniature setup of a dam and centimeters are displayed as meters on the website to simulate the real-life dam system. Water level sensors are stuck to a plastic tub and water will be poured into the tub.

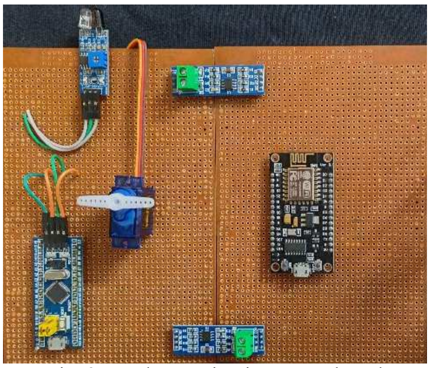

Fig. 3. Hardware Circuit on PCB board

Here, two water level sensors are used to cover the full height of the tub and scales are mentioned alongside the sensor (Fig.4). An IR sensor is kept near the servo motor so that it can detect any obstacle near and stop the opening of the floodgate if any obstacle is detected.

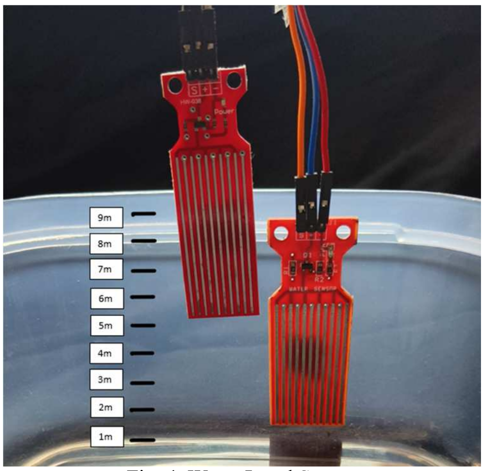

Fig. 4. Water Level Sensor

In the complete hardware setup is shown in Fig.5., the sensors from the tub will be connected to the PCB board circuit.

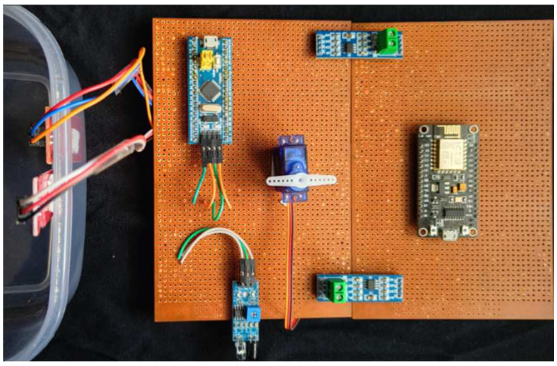

Fig. 5. The Hardware Setup

The website will then show the water level, whether an obstacle is present near the flood gate and the status of the floodgate. Background color changes according to the level of water and obstacle as shown in the below Fig.6, Fig.7, Fig.8, Fig.9, Fig.10, Fig.11.

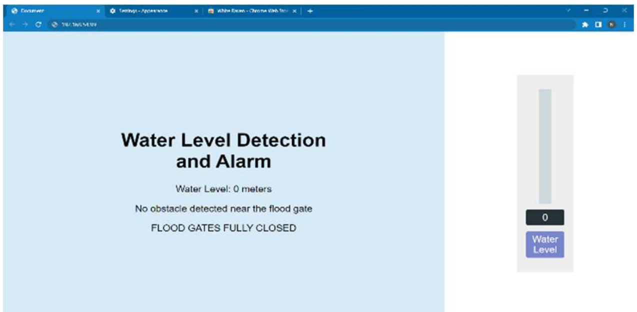

Fig. 6. Water level is ‘0’ and flood gates are closed

Fig. 7. The water level is ‘3m’ and flood gates are 25% opened

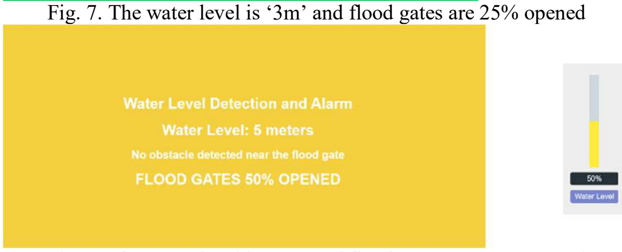

Fig. 8. The water level is ‘5m’ and flood gates are 50% opened

Fig. 9. The water level is ‘7m’ and flood gates are 75% opened

Fig. 10. The water level is '9m' and flood gates are 90% opened

Fig. 11. The water level is '9m' and flood gates are closed because an obstacle is detected

If an obstacle is detected, the background will turn red and the floodgate will be closed. The white background is for low water levels, green is for normal water levels, yellow is for water levels of more than 75%, Orange color is if the dam is almost filled and red is for fully filled. IFTTT will send a notification if the water level is too high. The notification will be received by mail and mobile for the registered users as shown in the picture below. Using the POST and GET methods the mail and the message will be sent. The link can be modified and pasted into the main code of ESP8266. There are many applets in IFTTT that can also be used to get similar output and push notifications.

Fig. 12. If a web request is received, then mail and SMS are sent.

Here, we used "Webhooks"," Email" and "Message" applets (Fig.12) to send alert notifications to the given mail id and phone number (Fig.13 and Fig.14).

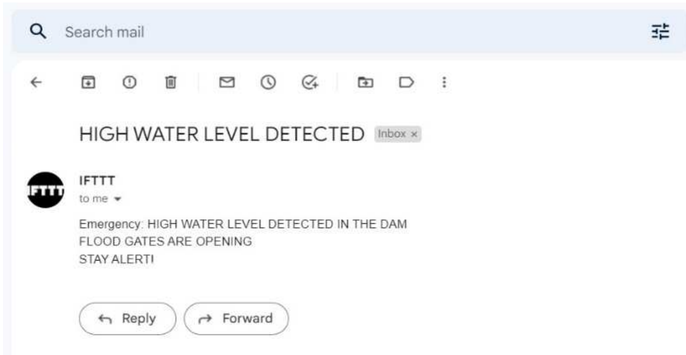

Fig. 13. The water level is high, mail sent by IFTTT

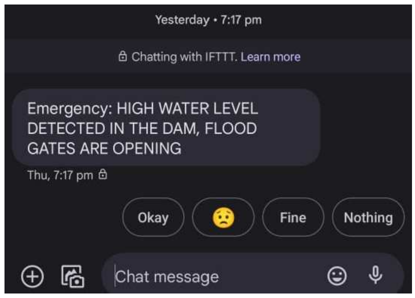

Fig. 14. The water level is high, SMS sent by IFTTT

IX. Conclusion

Our project is a miniature version of a real-life dam. The development of a smart dam system using RS-485 serial communication protocol between a single-chip embedded controller ARM Cortex STM32F103C8T6 and ESP8266 has shown promising results. The system includes a website that has been created to update the water level and floodgate status live. In case of an emergency, a notification will be sent using IFTTT. It also has the capability to reduce potential damage by automatically opening the floodgate based on the water level and obstacle detection. In real dam, some stronger and reliable sensors like Pressure Transducers, Radar Level Sensors, Hydrostatic Pressure Sensors, Acoustic Doppler Sensors, Guided Wave Radar Sensors can be used to measure water level, Omega OSXL450 and E2T MI3 Infrared temperature sensors for obstacle detection and Hydraulic or pneumatic Actuators, Electric motors, Screw Jacks, and chain drive systems can be used for opening flood gates. Along with these, we can use smart methodology we introduced in this paper. In the future, the system's accuracy and reliability can be improved by incorporating machine learning for predictive analytics and more advanced decision-making capabilities. This system can be integrated with other smart city infrastructures such as weather monitoring or emergency networks to make it a more comprehensive approach to flood management and response to emergency situations.

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