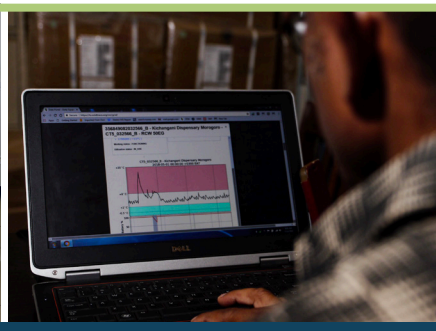


REMOTE TEMPERATURE MONITORING OF TANZANIA'S VACCINE COLD CHAIN IMPROVES VISIBILITY INTO EQUIPMENT PERFORMANCE

The technology shows promise to improve cold chain system monitoring, performance, and planning if challenges and risks are managed

November 2022

Remote temperature monitoring (RTM) is an important part of the cold chain system for vaccines to ensure their potency. In Tanzania, the Ministry of Health (MOH) made a significant investment in cold chain equipment (CCE) for the vaccine supply chain and rapidly expanded vaccine availability, creating an opportunity to also invest in more proactive monitoring of CCE performance. The country's experience so far with RTM demonstrates the promises and challenges of this technology, as well as highlights what factors should be considered when implementing or scaling up this monitoring approach to improve performance and manage risks.

BACKGROUND

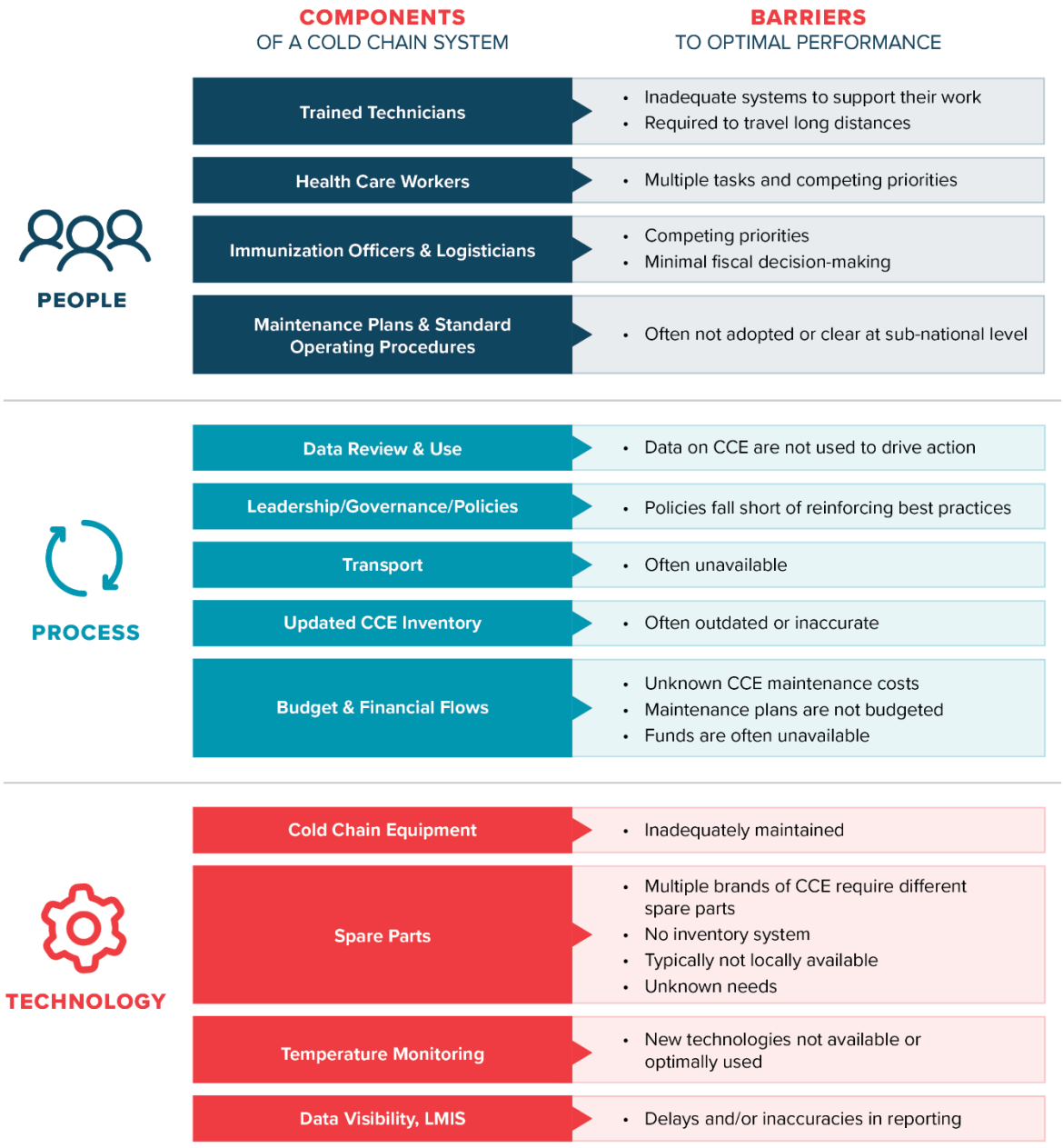
Vaccines require narrow temperature ranges — typically +2°C to +8°C at the health facility level — to preserve their quality. Even with optimized CCE, temperatures can fluctuate or equipment can break down, requiring immediate action to keep the cold chain cold, and prevent loss of vaccine quality.

Ensuring CCE maintenance and performance has been a widely acknowledged challenge across the world since the introduction of vaccines.[1,2,3,4] **Figure 1** shows the components of a cold chain system and common barriers to optimal performance.

To enable better monitoring of the temperatures in the cold chain and a quicker response when temperatures fall outside the required range (temperature excursions), the industry has improved its temperature monitoring technology through mobile and wireless capability. The most recent product type on the market is a remote temperature monitoring device (RTMD), which constantly monitors CCE temperatures, notifies staff through text alerts of any temperature excursions, and uploads temperature data to a dashboard for improved monitoring of CCE maintenance needs to keep the equipment functioning properly.

In 2017, the Tanzania MOH's Immunization and Vaccine Development program (IVD) scaled up use of RTM technology by investing in the installation of about 5,000 RTMDs in existing CCE at health facilities and district warehouses across the country. Through this nationwide use of RTMDs , IVD aimed to improve CCE performance to ensure vaccine potency, reduce wastage, improve monitoring of CCE performance, and better track CCE maintenance to inform long-term equipment planning needs.

Figure 1. Components of a cold chain system and common barriers to optimal performance



THE PROCESS FOR SCALING UP RTMDS IN TANZANIA

Installation of RTMDs. From early 2017 through the end of 2021, IVD, the MOH, and the President's Office-Regional Administration and Local Government (PORALG) led a phased introduction of the new RTMDs. Partner JSI Research & Training Institute, Inc. (JSI) and the RTMD manufacturer and analytics team, Nexleaf Analytics, supported this scale-up through trainings, technical assistance, and financial support. Regional and district immunization and vaccine officers (RIVOs and DIVOs) conducted ongoing monitoring and troubleshooting, shared lessons learned with each other through WhatsApp groups, and facilitated peer-to-peer support.

The RTMDs that IVD selected, called ColdTrace 5, are installed close to the CCE (often fixed to a wall to ensure security) with up to four sensors placed inside the CCE to read the temperature across multiple points. An external sensor reads the ambient temperature. The devices require a SIM card linked to a telecommunications network which collects data every 10 minutes, then automatically uploads these data to a server via the mobile network. The RTMDs

are primarily powered by the electrical grid or solar panels; they have built-in batteries that will power the devices for up to four hours in case of a power outage or low solar energy.

Integration of RTMD data in existing vaccine data system. JSI and Nexleaf integrated RTMD data into Tanzania's Vaccine Information Management System (VIMS) , which tracks vaccine supply data. Combining CCE inventory management data with vaccine stock data created a single place for all vaccine supply chain data. A separate web-based dashboard is available for additional details and further data analysis on RTMD.

Incorporation of RTMD data into data review processes. Eight districts incorporated RTMD data into their routine data review processes, using a structured process for data review and problem solving through peer-to-peer learning and performance monitoring. The immunization national technical working group and regional health review meetings also incorporated RTMD data in their reviews.

Transition of ownership to the government. The final step in the RTMD scale-up process was to transition ongoing monitoring, management, and financial responsibility for data and text message costs to the government. In the government budget for the 2020–2021 fiscal year, PORALG included the data and text message costs required to continue transmitting data after partner support ended. PORALG was instrumental in this transition, ensuring that districts understood the responsibility and registering SIM cards under the government for full ownership.

BENEFITS AND POTENTIAL BENEFITS OF RTMDS IN TANZANIA

Improved visibility into CCE maintenance and use. Two distinct responses were noted with RTMD use and integration of RTMD data with VIMS. First, response to temperature excursions was immediate, which was reflected in temperature data. For example, data showed temperatures returning to the required range when a technician replaced a CCE heating element immediately after noting the issue on the dashboard, as shown in **Figure 2**.

Second, supervisors and cold chain technicians tracked CCE performance remotely and followed up with facility-level health care workers (HCWs) to address immediate concerns, which was also reflected in temperature data. For example, data showed that temperature returned to the required range after a DIVO remotely diagnosed the need for a thermostat adjustment, and a facility HCW resolved it with the DIVO's guidance over the phone, as shown in **Figure 3**. The ability for district and regional officers to guide facility-level staff by phone after diagnosing an issue reduces the need for travel to a facility and the associated time and costs.

Figure 2. CCE temperature readings before and after a technician replaced the heating element after being alerted to an excursion by RTMD data

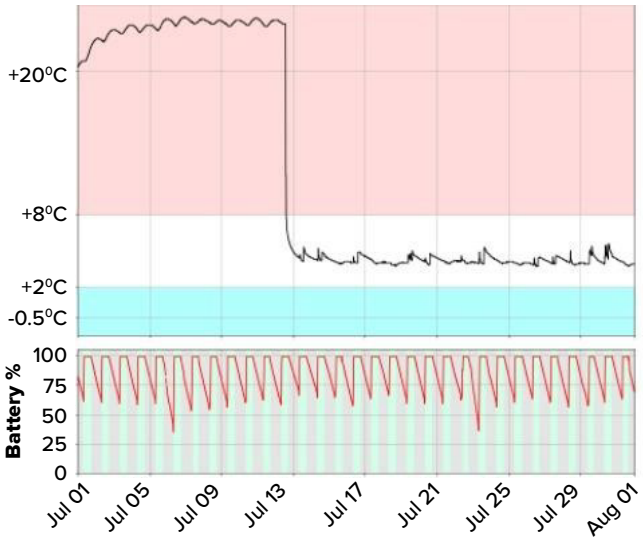
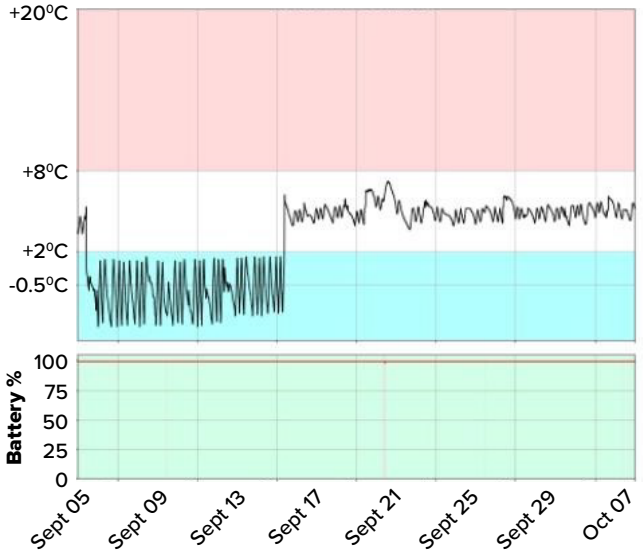
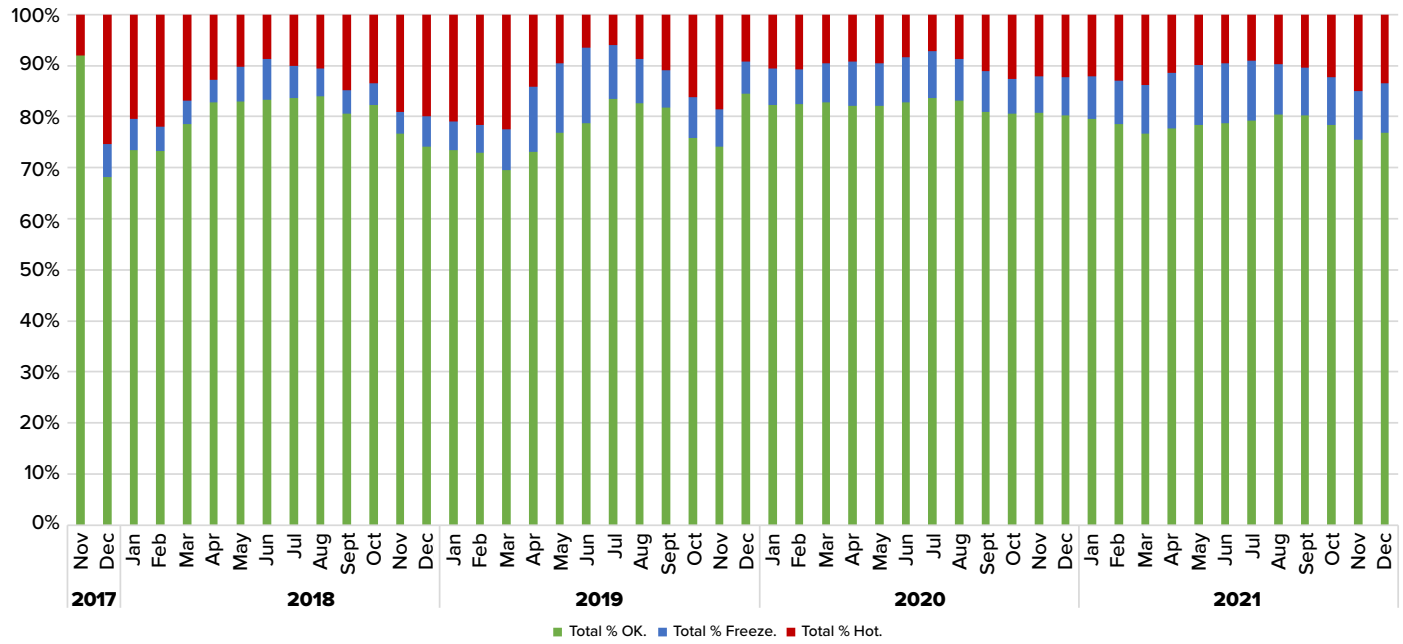


Figure 3. CCE temperature readings before and after a HCW adjusted the thermostat with phone guidance from a DIVO



Potential for improved cold chain performance. Of the RTMDs sending data, temperatures were stable during 2021 across the country, with about 80 percent of time in the ideal temperature range, yet with greater fluctuation of hot and cold excursions during the first three years of implementation. **Figure 4** shows total time in the ideal temperature range, hot range, and cold range.

Figure 4. Total time in the ideal temperature range, hot range, and cold range of all devices sending data, November 2017–December 2021



While promising, these results fall short of showing significant improvement in equipment performance and in how data can drive action. Challenges to implementation (see a discussion of these below) may have prevented the ability to focus on the change management required to influence a more proactive maintenance system to respond to temperature excursions.

A second set of eyes for health care workers. Text alerts from RTMDs helped ensure that HCWs did not miss temperature excursion alarms. The alerts drove immediate action and, according to HCWs, provided peace of mind that vaccines were in the ideal temperature range. This was particularly important when HCWs were not present at the facility or storage site.

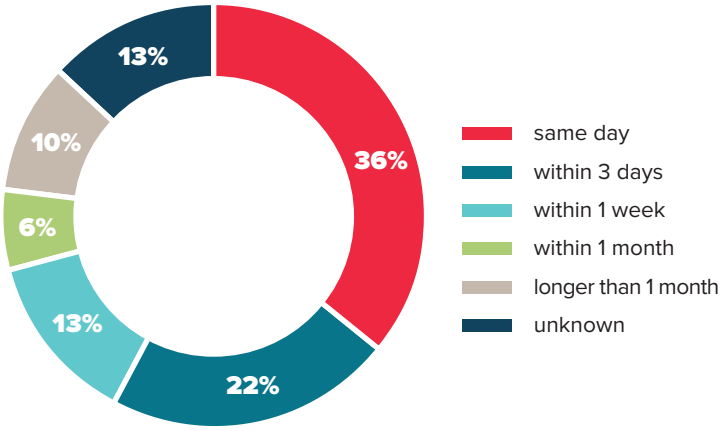
Increased government support for the cold chain system. Government support for RTMDs and the cold chain system increased. At the national level, IVD committed to procuring and installing devices for remaining facilities in mainland Tanzania and Zanzibar. PORALG continued to monitor RTMD performance and provided directives for regions and districts to resolve RTMD and CCE issues in a timely manner. Districts included ongoing RTMD data costs in their facilities' annual budgets.

Demonstrated potential for predictive analytics. With the amount of temperature data now available through large-scale RTMD deployment, Tanzania can develop more predictive analytics for CCE maintenance, spare parts planning, and long-term CCE replacement. Joining cold chain technicians with data analysts who can analyze complex patterns and trends in the system could help identify immediate actions to resolve maintenance issues, both remotely and on site, as well as predict failures and prevent them by planning for required maintenance and spare parts, increasing equipment uptime and preventing breakdowns.

CHALLENGES TO RTMD SCALE-UP IN TANZANIA

Increased need for a reliable cold chain maintenance system. Real-time visibility into CCE performance raised awareness of the need for a reliable maintenance system. Results of a maintenance survey indicated that in more than 50 percent of CCE breakdowns, a technician responded within three days, as shown in **Figure 5**. Anecdotally, DIVOs are able to resolve most of the minor maintenance issues, and cold chain technicians are able to resolve the more complicated issues.

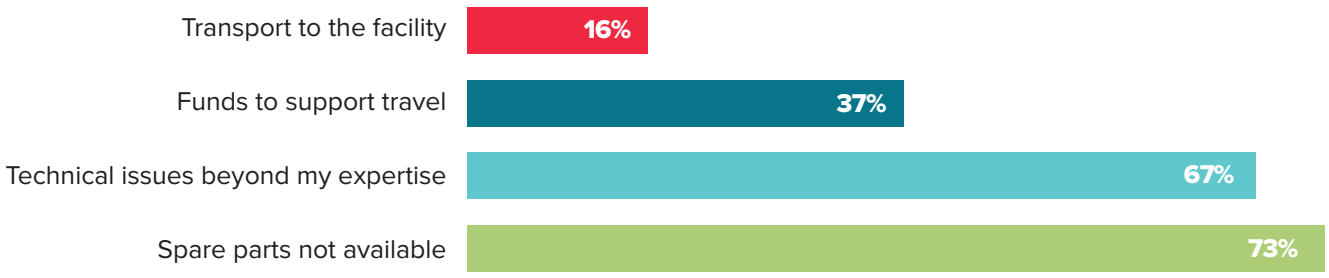
Figure 5. Time for technician to respond to CCE breakdown



However, respondents in the maintenance survey noted several barriers to corrective maintenance: transport to the facility, funds to support travel, technical issues beyond a CCE technician's expertise, and lack of availability of spare parts **(Figure 6)**.

Network availability. While the telecommunications network is growing in Tanzania, not all networks are available everywhere, and the country still has zones that have unreliable or unavailable networks. Other temperature-monitoring devices, such as 30-day temperature recorders (30DTRs), are more appropriate for settings without reliable telecommunications networks.

Figure 6. Barriers to corrective maintenance of CCE



Modified telecommunication requirements. In 2021, two changes in telecommunications requirements caused delays in RTMD scale-up. First, a change in regulations prevented external phone numbers from topping up SIM cards; instead, top-ups had to be done on SIM cards directly every three months or at the telecommunications office, placing the responsibility on facility-level staff instead of a DIVO or RIVO. This added a level of complication and extra effort for HCWs.

Second, the telecommunications companies required different SIM cards for cell phones than for other devices, such as RTMDs. This change, as well as the government taking ownership of the SIM cards, required all new SIM cards to be purchased and installed. This process has caused delays, partly due to a requirement for in-person registration and, in some cases, long distances to the locations of telecommunications service providers. While district management has facilitated this process, the shift has negatively impacted the number of devices sending data.

Issues with device functionality. The delay in change of SIM cards and subsequent backlog of data stored on the device required a reset and cleaning of the software, which calls for higher-level technicians providing on-site care to resolve this issue. This has been complicated to implement in a timely manner due to the large number of devices.

Competing priorities. All levels of the government — the MOH, IVD, PORALG, RIVOs, and DIVOS — played an active role in planning, installing, and monitoring RTMDs and CCE. However, these government partners had to contend with competing priorities while integrating this technology into their regular work processes, resulting in installation delays. While transitioning ownership and financing from partner support to districts and facilities, it also took time for this new responsibility to be adopted into work processes.

The COVID-19 pandemic. Lockdowns, travel restrictions, and the shift of focus to COVID-19 prevention delayed RTMD training and installation.

LESSONS LEARNED

Government ownership and commitment is key. From initial planning through implementation, the government has supported this technology because of the demonstrated need and the utility of data for CCE performance. PORALG has been instrumental in ensuring health facility budgets for the data and text message costs and transitioning these costs to regional administrations. PORALG also provides follow-up for devices not sending data by consistently reminding subnational levels to take action for the devices to continue sending data and to act on every alert. Districts have demonstrated ownership through registration of SIM cards and payment of data costs.

Centralized versus decentralized ownership. In Tanzania, the MOH led RTMD scale-up, but when technology challenges arose, staff at the district and regional levels worked to resolve them, which was often time consuming and caused delays in getting the devices up and running. Additionally, health facilities had the budget to pay for text and data costs, but the data is not being used at the facility level from a management perspective; it is mostly being used by districts and district councils. As a result, facilities may not prioritize paying for it.

These experiences in Tanzania show that governments should consider whether management and financing should be centralized for a country-wide rollout of new technology.

Include health care workers in implementation and provide high-quality training. The HCWs who directly monitor RTMDs need to be included in installation of the device and need robust training, not just on reading the temperature data but also on managing device maintenance and repairs. This helps to fully invest them in the new technology and reinforces data use at the facility level. Getting regular feedback from supervisors on CCE performance would also help encourage HCWs to pay for the new technology and ensure it works.

Ensure time and financial support for change management. Change management is particularly important to reinforce data use practices and to incorporate temperature data into regular review processes. Additionally, the government must have immediate access to data dashboards.

Consider all technology options and context. The type of RTMD installed in Tanzania is one of many options available now, including devices that are already built into the CCE or that use global SIM cards. Considering the many challenges to scaling up the RTMDs in Tanzania and ensuring that they all are sending data, different options could be explored — such as global SIM cards — for any additional expansion. While global SIM cards may have higher data costs, they may be more reliable, helping to avoid the additional operational costs that IVD has experienced with the ongoing telecommunications issues. If global SIM cards are too expensive, using local SIM cards could be explored.

Consult with telecommunications companies. Working with telecommunications carriers before introducing RTMD technology can help governments understand requirements and anticipate the impact of future changes to telecommunications policies.

Apply a systems perspective. A key insight was to consider the entire cold chain system in any intervention. As RTMD data became more available, the need for reliable CCE maintenance was elevated, which then highlighted maintenance system gaps. New CCE installed during this time required shifting RTMDs to the new equipment and updating the CCE inventory — both for inventory management and for the RTMD dashboard — to accurately link RTMDs to the correct CCE. Consistent engagement with key stakeholders is important to link multiple cold chain components and to clarify how components influence each other.

Improve the maintenance system. With investments in CCE and temperature monitoring—globally and in Tanzania—maintenance must be prioritized to protect those investments. New technologies and data visibility present an opportunity to innovate and work toward an effective maintenance system, building on successes to date and developing solutions for the gaps entrenched in current systems.

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