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A REAL-TIME EMERGENCY RESPONSE WORKSTATION USING A 3-D NUMERICAL MODEL INITIALIZED WITH SODAR

Bryan S. Lawver and Thomas J. Sullivan
University of California
Lawrence Livermore National Laboratory
Livermore, CA 94551-0808

Ronald L. Baskett
EG&G, Inc
Pleasanton, CA 94566

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DISCLAIMER

A REAL-TIME EMERGENCY RESPONSE WORKSTATION USING A 3-D NUMERICAL MODEL INITIALIZED WITH SODAR*

Bryan S. Lawver and **Thomas J. Sullivan**
Lawrence Livermore National Laboratory
Livermore, CA 94551
and
Ronald L. Baskett
EG&G Energy Measurements, Inc.
Pleasanton, CA 94588

ABSTRACT

Many emergency response dispersion modeling systems provide simple Gaussian models driven by single meteorological tower inputs to estimate the downwind consequences from accidental spills or stack releases. Complex meteorological or terrain settings demand more sophisticated resolution of the three-dimensional structure of the atmosphere to reliably calculate plume dispersion. Mountain valleys and sea breeze flows are two common examples of such settings. To address these complexities, we have implemented the three-dimensional diagnostic MATHEW mass-adjusted wind field and ADPIC particle-in-cell dispersion models on a workstation for use in real-time emergency response modeling. MATHEW/ADPIC have shown their utility in a variety of complex settings over the last 15 years within the Department of Energy's Atmospheric Release Advisory Capability (ARAC[1]) project. The models are initialized using an array of surface wind measurements from meteorological towers coupled with vertical profiles from an acoustic sounder (sodar). The workstation automatically acquires the meteorological data every 15 minutes. A source term is generated using either defaults or a real-time stack monitor. Model outputs include contoured isopleths displayed on site geography or plume densities shown over 3-D color shaded terrain. The models are automatically updated every 15-minutes to provide the emergency response manager with a continuous display of potentially hazardous ground-level conditions if an actual release were to occur. Model run time is typically less than 2 minute on 6 megaflop (~30 MIPS) workstations. Data acquisition, limited by dial-up modem communications, requires 3 to 5 minutes.

INTRODUCTION

With the speed of today's computer workstations coupled with advances in automated data acquisition, sophisticated emergency response systems can now provide reliable information on the consequences of accidental atmospheric releases from facilities within minutes. Moreover, with the addition of continuous stack and ambient air monitors, the system can double as an environmental monitoring and assessment tool.

The Lawrence Livermore National Laboratory Atmospheric Release Advisory Capability (ARAC) has over 18 years experience in developing such systems. We have supported the Departments of Energy and Defense with local, regional and global scale atmospheric dispersion models coupled with real-time meteorological data acquisition. The heart of our system is the three-dimensional diagnostic MATHEW/ADPIC dispersion model which has been tested in numerous settings over the last decade.[2,3] We are currently developing a workstation which includes the data acquisition and model computation. This

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workstation dedicated to a specific problem will monitor and report the atmospheric dispersion of routine and emergency releases.

BACKGROUND

Commencing with ARAC's support of the federal response to the Three Mile Island nuclear power plant accident in 1979, there has been considerable interest in ARAC models and systems technology. Several countries and international agencies have received copies of the ARAC models (Italy, Japan, Spain, Brazil, Sweden, India, and Israel) during the past decade; some have developed ARAC-like national response systems. Agencies such as the CEC and IAEA have served as conduits for the exchange of information concerning dispersion models and systems for supporting emergency response. Since the Chernobyl accident and the greatly changed international geopolitical status, there have been numerous contacts with East Europe, Russia and third world countries. Most contacts have indicated a strong desire to have some components of the ARAC-developed emergency response support system technology.

In October, 1988, the IAEA supported an LLNL/ARAC hosted workshop to define the requirements for a local environmental monitoring and emergency response system which would be suitable for less-developed countries. These are countries that have minimal infrastructure and technical bases for nuclear power facilities. Since that workshop, advances in computer workstations, monitoring technology and system development at ARAC have converged so that it is now feasible to deliver affordable standalone systems to these countries.

Besides foreign countries without adequate emergency response systems, the emerging area of environmental clean-up offers an opportunity for a dedicated workstation system to monitor and support the clean-up effort. The clean-up situation is typically limited to specific hazardous species and not the whole suite of possible accidents from an operating facility (nuclear, petrochemical, etc.). The workstation can produce daily exposure reports for the clean-up site plus respond quickly to alarms with emergency reports.

SYSTEM COMPONENTS

Figure 1 illustrates the essential components of the system. Surface and upper air meteorological measurements are needed to specify the wind field in the vicinity of the facility. Conventional wind speed, wind direction, and temperature sensors on 10 to 60 m high **meteorological towers** are used to measure the lowest layer near the ground. The number and placement of these towers is determined by the complexity of the terrain and meteorological flow regimes within 10 km of the facility. Each tower has a programmable data logger which formats and transmits data to the workstation once every 15 minutes over dial-up or leased line modems. Most facilities with hazardous material already have real-time meteorological systems in place which could be interfaced with the stand-alone workstation.

A **s**ound **d**etection **a**nd **r**anging system or **sodar** is used to initialize the vertical profile of winds in the model. Sodars emit pulses of sound upward into the atmosphere from a phased-array of speakers. The speakers are then used to measure the faint return sound waves which are reflected downward from the turbulent structure of the atmosphere. The Doppler shift in the frequency of the return signals is used to determine wind speed and direction at several layers in the atmosphere up to 1 km above ground. In addition, the mixing height is derived from the intensity of the return signal. It is important to place the sodar in a relatively quiet surrounding not affected by other noise sources. Wind profile data is collected on a local data logger and transmitted to the workstation once every 15 minutes over dial-up modem lines.

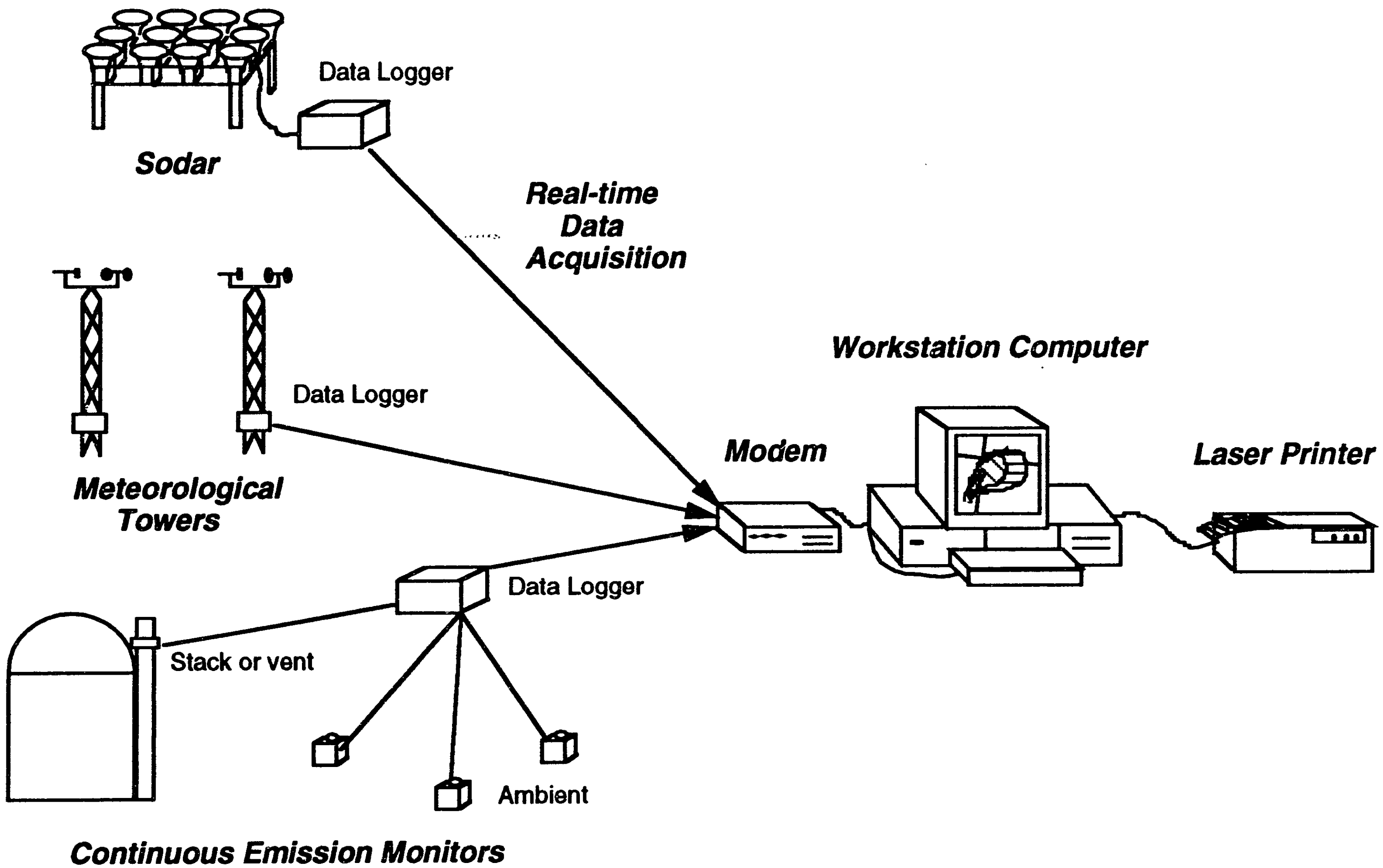

Figure 1. Stand-Alone Monitoring/Emergency Response System

Continuous emissions monitors (CEMs) are configured for stack and ambient air concentration of real-time measurements of toxic and radiological hazardous materials. Stack monitors provide a direct measurement of the release rate from routine or upset conditions in stacks or vents. The monitors would be networked to a single computer-controlled data logger which would transmit periodically to the workstation. The monitoring data logger can be programmed to send high readings immediately and transmit routine background concentrations at a lower priority.

The **workstation computer** uses a RISC-class UNIX-based platform with color graphics monitor, disk, modems and laser printer. This configuration is common in engineering offices where Fortran applications are common. The fast personal computers do not calculate fast enough to support the dispersion models. The multitasking capability of UNIX is important to support the concurrent data collection effort, the dispersion modeling and the printing of results to the laser printer.

DISPERSION MODELING ENVIRONMENT

Parameters for each dispersion modeling environment are derived from two sources as shown in figure 2. One source are those parameters specific to each site such as the region of interest, surface roughness, and other parameters which will stay unchanged for the life of the modeling system. A second source of parameters are those which can be derived from the current environment such as time, stability class, wind parameters and release rates. Each 15 minutes, a modeling cycle begins with the polling of the various data loggers for their current data. When the polling is complete, derived parameters are computed and the dispersion models are executed. After the model calculation is complete the concentration data is contoured and displayed either to the graphics monitor or the laser printer. Other data bases which support the models include topography for adjusting the wind field, a dose

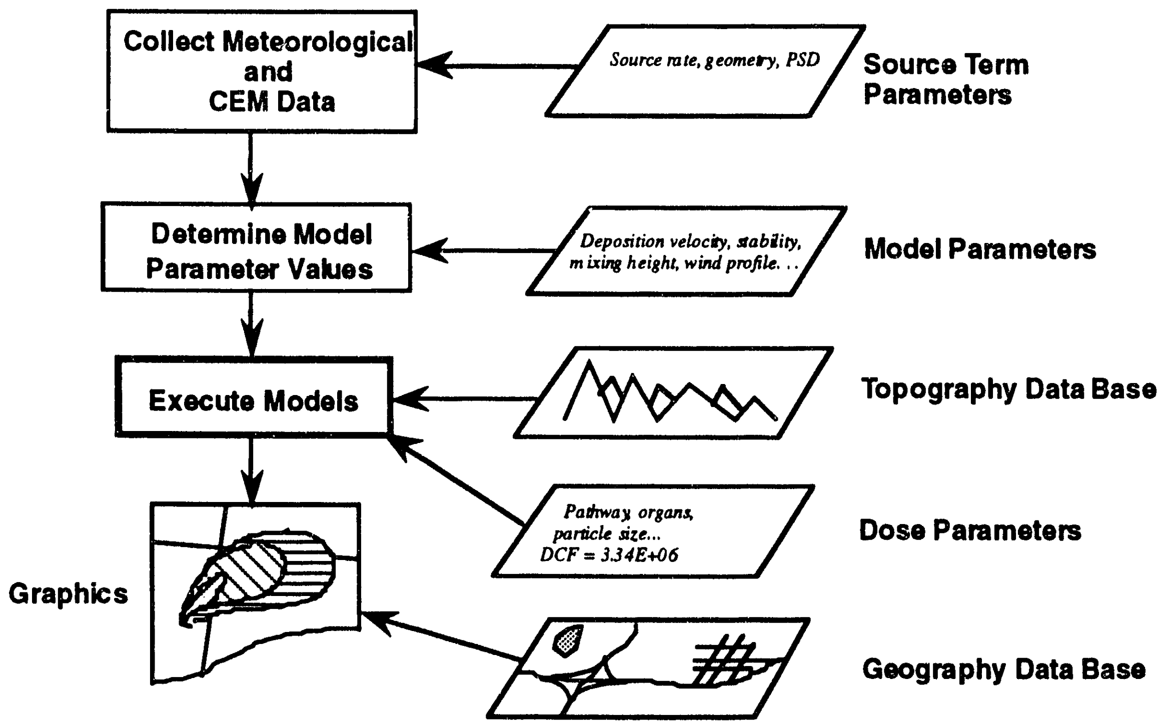

Figure 2. Modeling Environment and Supporting Data Bases

conversion data base for converting air concentrations to dose, and a geographic data base for use in generating contour plots.

This same modeling cycle could be initiated at any time in event of an alarm with the last available data from the data loggers used. In addition, a daily, weekly or even monthly or yearly report can be computed off hours. The current configuration uses less than half the tasks.

DISPERSION MODEL

A **three-dimensional, diagnostic numerical model**, employs the following series of three codes as illustrated in Figure 3.

MEDIC - Meteorological data interpolation code
MATHEW - Mass-adjusted three-dimensional wind field
ADPIC - Atmospheric dispersion by particle-in-cell

MEDIC uses an inverse-distance-squared ($1/R^2$) weighting of the wind speed and direction measurements in combination with boundary layer power laws to initialize the horizontal wind field for MATHEW. MATHEW minimizes the divergence in the initial wind field by adjusting the horizontal vectors and generating vertical winds according to mass consistency. ADPIC uses this wind field to transport the release from single or multiple sources over the grid. Diffusion is accomplished by either gradient (K-theory) or Monte Carlo schemes using thousands of Lagrangian marker particles. Sources may be either puffs or plumes with time-varying release rates. Half-life decay, particle-size-dependent settling, dry deposition and rainout are computed for each time step for each source. Post processing graphics routines draw the contours of interest, such as dose, air concentration or deposition over maps which are digitized for the region.

The boundary layer power law equation of MEDIC uses the sodar data. Traditional sources of upper air data are not as easily integrated into a workstation system. During heavy rain or high winds when the background noise masks the return sound, the workstation system derives an atmospheric wind profile from one of our surface towers which has a 10 meter and 40 meter measurement levels.

The CEM data logger provides source rates for the dispersion model, ADPIC. The data logger is a simple office computer running a laboratory automation package which comes with hundreds of interface modules for most laboratory instruments. It passes data to the model workstation where it is translated into input for ADPIC.

RELIABILITY AND PERFORMANCE

We have not made specific uptime measurements but the occasional failure is for one cycle of data collection and model prediction and is usually related to unreliable data collected from a specific tower. Collection of meteorological data and calculating the models have been operating continuously since late 1991. The more difficult task has been to locate and interface to CEM instruments which are capable of real time operation with enough sensitivity to produce readings other than zero or background. This task is just now achieving its goal by integrating ion-chamber stack monitors from a tritium handling facility at LLNL. The workstation treats each 15 minute period as a separate cycle so if any step fails or hangs that cycle is abandoned and a new cycle is started. This virtually guarantees that some results will be available even after several days of vacation or inattention by the support team.

The choice of data loggers to interface to instruments has reduced the complexity of the entire system and provided a simpler support effort. If problems develop with the instruments or maintenance is required, the data logger isolates those instruments from the workstation system. The workstation alters its mode of operation depending on which data loggers are available. Missing release rate channels cause the system to revert to a normalized source rates which show dispersion without providing magnitude levels for contours. Missing meteorological stations are ignored by MEDIC except for a missing upper

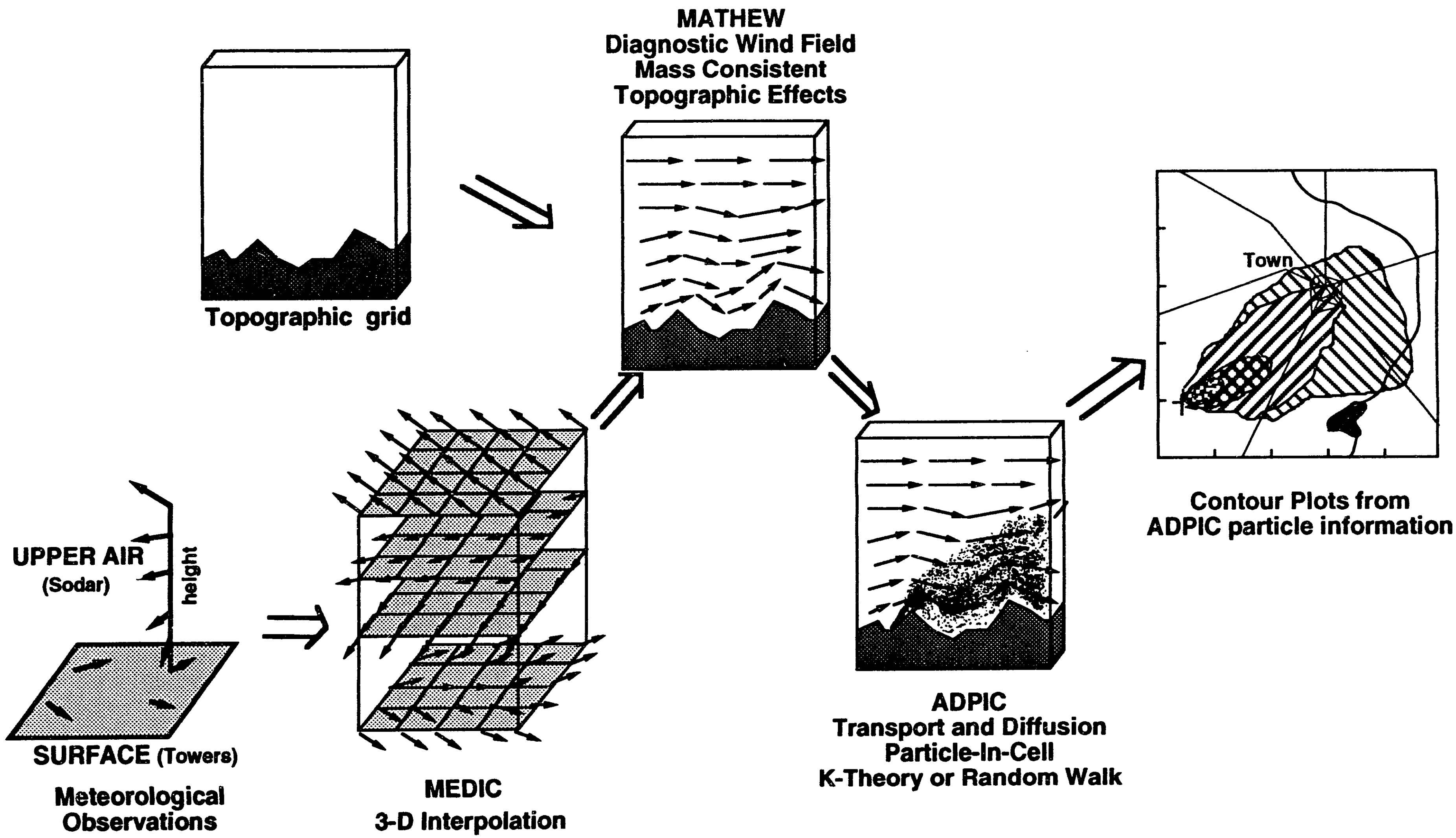

Figure 3. MATHEW / ADPIC Modeling System

air profile. If this is the case, winds aloft are projected from a two level surface tower. If too much data is missing then no report is generated.

The numerical calculational performance of the workstation is critical to the expectation that a complex 3D dispersion model can be included with this system. Fortunately there are several vendors of high end, low cost engineering workstations which meet the calculational speeds necessary. Unfortunately the common office desktop computer is still too slow.

CONCLUSIONS

The cost, reliability and performance of workstations provide an opportunity to utilize advanced real-time dispersion modeling for facility monitoring and emergency accident assessment. Near continuous (15 minute update resolution) displays of real-time assessments for ambient facility effluent dispersion conditions can reside on workstation displays in facility control rooms and emergency coordination centers. The workstation in the emergency response center now can perform tasks which previously required very large computers and the results were available only in a post accident evaluation phase.

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