# Proficient Helium Recovery System and Analysis by Computational Fluid Dynamics

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*Abstract*— In order to increase the efficiency of helium recovery system present in the market, proficient helium recovery system and analysis by computational fluid dynamics provides the comprehensive solution. The present system is used for testing various components like condenser, evaporator, air conditioner connecting tubes etc. This system involves a rubber helium recovery bag and float level indicator with proximity sensor. The overall main leakage of helium is from the rubber bag. The leak is horizontal due to the expansion and contraction of the rubber bag. This existing system with new rubber bag is capable to test few number of components and the components number reduce further due to aging of rubber recovery bag. Thus scheming and fabrication of cast iron recovery tank will retain the components number and will be the best solution for this system. This implementation involves various analysis, sketches, additional equipments and safety equipments.

***Keywords:*** helium recovery system, proficient helium recovery system, computational fluid

## I. INTRODUCTION

Helium leak testing can be performed in several ways. Most commonly, the assembly is pressurized with helium and placed inside a vacuum chamber, explains Jacques Hoffman, president of Inter Tech Development Co. After air is evacuated from the chamber, a mass spectrometer tuned to helium samples the inside of the chamber. The chamber is usually designed specifically for the test assembly to minimize the amount of air that must be evacuated-and thus minimize cycle time. In a variation of the vacuum method, air is not evacuated from the test chamber. Instead, the pressurized assembly is simply left alone for a set length of time to allow escaping helium to accumulate in the chamber. If the concentration of helium increases, the assembly has a leak.

Helium can be found all over the universe, although it isn't widely distributed on Earth. Its most frequent form is gas. It shares many characteristics with other noble gases. Helium doesn't form compounds easily with other elements. It is also very stable. But as the facts earlier show, the element is very usable. Its symbol in the periodic table is He. Its stability and non-reactive nature makes it the perfect tool for handling unstable materials. The element was discovered in 1868 during a solar eclipse. It took scientists 30 years to extract and isolate the gas from the clevite mineral. The gas is not prevalent on Earth. It is usually extracted from natural gas. The typical amount found ranges from 2 to 7%. It didn't take long for governments to realize its usefulness in military operations. Access to it was restricted during the two World Wars. In its purest form, the element doesn't pose any health risks. However, inhaling excessive amounts has its risks. The danger is the gas functions as an asphyxiate. Inhaling helium from pressure tanks can damage the lungs. The variants found in weather balloons may have other elements that are unhealthy to breathe. Its atomic number indicates there are two electrons and two protons in a neutral helium atom. Its most vital properties are density, melting and boiling points, state of matter and atomic mass. The density is 101.325 kilopascals (kPa) and 0.1786 grams per liter at 32°F (0.0°C). Its atomic mass is 4.0026 grams per mole .Solid and liquid helium can only manifest in high and low temperature settings. Either condition cannot manifest under normal pressures. -458 F (0.95 Kelvin) is the melting point. The boiling point is -452°F (4.22 Kelvin).

One of the more interesting uses of helium is in cryogenics. This field is concerned with low temperature phenomena and its production. Most of the helium produced today is used for cryogenics Helium is one of the most common elements in the universe. It is called a noble gas because it doesn't chemically interact with elements. Its atomic number is 2 and the weight is 4.002. In its natural state, it doesn't have any smell, taste or color.

### A. *Leak Testing Methodologies:*

#### 1) *Ultrasonic Measurement:*

Any type of leak emits a sound and, depending on the size of the leak, the frequency of the leak can be higher or lower. Very small leaks emit a sound with a frequency which is too high for our ears to detect so an ultrasonic leak detector is used in this case. Ultrasonic leak detectors are generally hand held devices which are used with a pair of headphones, a meter, a sensitivity adjustment, a nozzle and some level of software. More complex systems can be used when it is necessary to automate the process in a production environment for example, where more leak detection points are potentially present. This method is not reliable in complex systems where ultrasonic sounds can be produced by multiple leaks but other sources too, which do not necessarily imply a leak (background noise). Also, the leak rate cannot be measured, but only estimated based on the frequency of the emitted sound. The sensitivity of the instrument is rather low as well, as it can reliably detect leaks only up to10-2 mbar ·litre/sec. For these reasons, this method is suited to finding large leaks, but it is not recommended for the fine leaks in a production environment.

Ultrasonic testing is based on the vibration in materials which is generally referred to as acoustics. All material substances are comprised of atoms, which may be forced into vibrational motion about their equilibrium positions. Many different patterns of vibrational motion exist at the atomic level; however, most are irrelevant to acoustics and ultrasonic testing. Acoustics is focused on particles that contain many atoms that move in harmony to produce a mechanical wave. When a material is not stressed in tension or compression beyond its elastic limit, its individual particles perform elastic oscillations.

When the particles of a medium are displaced from their equilibrium positions, internal restoration forces arise. These elastic restoring forces between particles, combined with inertia of the particles, lead to the oscillatory motions of the medium. A typical pulse-echo UT inspection system consists of several functional units, such as the pulse/receiver, transducer, and a display device. A pulse/receiver is an electronic device that can produce high voltage electrical pulses. Driven by the pulse, the transducer generates high frequency ultrasonic energy. The sound energy is introduced and propagates through the materials in the form of waves.

When there is a discontinuity (such as a crack) in the wave path, part of the energy will be reflected back from the flaw surface. The reflected wave signal is transformed into an electrical signal by the transducer and is displayed on a screen. Knowing the velocity of the waves, travel time can be directly related to the distance that the signal travelled. From the signal, information about the reflector location, size, orientation and other features can sometimes be gained.

*2) Bubble Test:*

This method consists of pressurizing the component (usually with dry air or nitrogen), submerging it into a water tank and watching for escaping bubbles. A leak in the component will produce a bubble stream, which can be less or more intense depending on the size of the leak itself. The size of the bubble will also depend on this factor. The theoretical sensitivity of this method is about 10-4 mbar·litre/sec, however the real sensitivity is lower (10-3 mbar·litre/sec) as it is influenced by factors like illumination conditions, water turbidity, unit location and placement and water movement. Bubble testing is the simplest, least expensive method of detecting and assessing leak rate.

The procedure is as the name implies: the part being tested is submerged in water, and the test operator visually observes and takes note of any bubbles escaping from the test part. Under the best test conditions, including good lighting, a very clear liquid, and a patient, alert operator, and a leak rate of 10-2 to 10-3 sccs can be observed (a 1-2mm bubble escaping).

*3) Pressure Decay:*

If we consider a component charged at a given pressure, any possible leak can be associated with a decrease of internal pressure. Therefore, if a component needs to be leak tested, it can be first charged (usually with dry air or nitrogen) at a set pressure and then its pressure can be monitored for a set amount of time. Pressure decay indicates the presence of a leak. This system is simple, compact and easy to use. It is cheap, dry and it does not require an operator’s judgment for its use. The leak detection sensitivity depends on the volume of the unit to be tested the pressure transducer resolution and testing time.

*4) Vacuum Decay Test:*

This method works in the opposite way of the pressure decay test. It is based on the on the evacuation of the part, and after the pressure has stabilized, any increase in pressure caused by test media entering the part is measured. This method is suitable only for parts which are able to withstand vacuum (thin walled parts cannot be tested due to the danger of collapsing). With respect to the pressure decay test, this method has the advantage of being less sensitive to temperature changes since the internal pressure is lower than the external atmospheric pressure.

Even if in the vacuum decay test it is not possible to get more than one atmosphere of pressure difference from inside to outside, using some solvents (i.e. alcohol, acetone or similar) exalts the pressure increment due to the solvent entering into the leak. This approach, however, has some shortcomings, such as the possibility of solvent freezing, causing temporary leak-stuffing, or elastomer gaskets becoming damaged by solvents.

*B. Existing System:*

Helium recovery is a cost saving in processes requiring the use of pressurised helium gas.

A recovery system's main components are:

- A backing helium economiser, capable of reusing up to 70% of the helium.
- A low pressure receiver tank, commonly a flexible globe that operates at atmospheric pressure.
- A helium compressor, with output pressure of up to 200 bar.
- A high pressure tank, where the compressed helium is stored
- A purity analyser,measuring gas thermal conductivity, which guarantees that the Helium concentration is adequate.
- A drying filter, to remove any humidity transported in the helium.
- An oil and particle filter that prevents contamination of the helium.
- A gas mixing unit, normally mixing He and $N_2$, in the required proportions.
- An automatic control system for the entire system.

## II. EXPERIMENTAL SETUP

Existing helium recovery system is made more efficient by bringing out various modifications and additional components to the existing model. The major leak should be arrested, inorder to increase the efficiency to the maximum figures. This major leak is arrested by replacing the helium recovery rubber bag with cast iron helium recovery tank. For practical installation of the recovery tank, various components have to be added to the system for both operational and safety purpose.

The modifications and additional components are:

- Cast Iron Helium Recovery Tank.
- Pressure Sensor.
- Pressure Indicator.
- Safety Valve.

 

Pressure sensor senses the pressure inside the tank with help of semiconductors, sensing is carried out inorder to start and stop the compressor. Pressure indicator is used to measure the pressure increase pressure sensor failure. Safety valve is a mechanically operated valve which is fixed to prevent blasting of helium tank.

By carrying out such modifications, various flaws of the existing system can be eradicated and satisfies the company's claims.The selection of a proper material, for engineering purposes is one of the most difficult problem .The best material is one which serve the desired objective at the minimum cost. The following factor should be considered while selecting the material.

- Availability of the material.
- Suitability of the materials for the working conditions in service.
- Cost of the material.

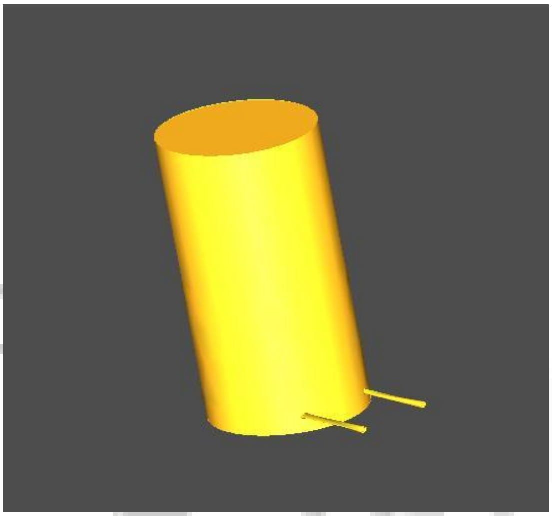

Fig. 1: Creo Diagram of Recovery Tank

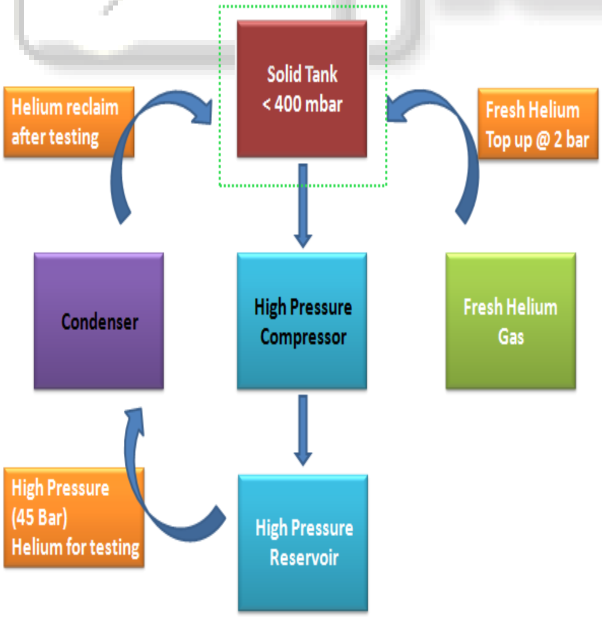


Fig. 2: Flow Block Diagram of Proposed System

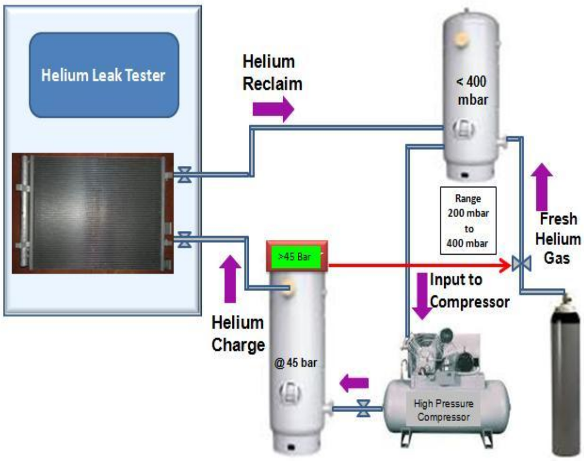


Fig. 3: Actual Flow Diagram of Proposed System

## III. EXPERIMENTAL ANALYSIS

FLUENT is a state-of-the-art computer program for modelling fluid how and heat transfer in complex geometries. FLUENT provides complete mesh flexibility, solving your own problems with unstructured meshes that can be generated about complex geometries with relative ease. Supported mesh types include 2D triangular/quadrilateral, 3D tetra-hedral/hexahedral/pyramid/wedge, and mixed (hybrid) meshes. FLUENT also allows you to re ne or coarsen your grid based on the own solution. All functions required to compute a solution and display the results are accessible in FLUENT through an interactive, menu-driven interface. The user interface is written in a language called Scheme, a dialect of LISP. The advanced user can customize and enhance the interface by writing menu macros and functions. Contact your support engineer for details. FLUENT, the solver, prePDF, the preprocessor for modeling non-premixed combustion in FLUENT. GAMBIT, the pre-processor for geometry modeling and mesh generation. TGrid, an additional preprocessor that can generate volume meshes from existing boundary meshes.

Alters (translators) for import of surface and volume meshes from CAD/CAE pack-ages such as ANSYS, CGNS, I-DEAS, NASTRAN, PATRAN, and others. You can create your geometry and grid using GAMBIT. See the GAMBIT documentation for details. You can also use TGrid to generate a triangular, tetrahedral, or hybrid volume mesh from an existing boundary mesh. It is also possible to create grids for FLUENT using ANSYS (Swanson Analysis Systems, Inc.), CGNS (CFD general notation system), or I-DEAS (SDRC); or MSC/ARIES, MSC/PATRAN, or MSC/NASTRAN (all from MacNeal-Schwendler Corporation). Interfaces to other CAD/CAE packages may be made available in the future, based on customer requirements, but most CAD/CAE packages can export grids in one of the above formats. Once a grid has been read into FLUENT, all remaining operations are performed within the solver. These include setting boundary conditions, defining fluid properties, executing the solution, refining the grid, and viewing and postprocessing the results.

Note that preBFC and GeoMesh are the names of fluent preprocessors that were used before the introduction of GAMBIT. You may see some references to preBFC and GeoMesh in this manual, for those users who are still using grids created by these programs. An important step in the setup of your model is the definition of the physical properties of the material. Material properties are de need in the Materials panel, which allows you to input values for the properties that are relevant to the problem scope you have defined in the Models panels. These properties may include the following:

- Density
- Heat capacity
- Thermal conductivity

Properties may be temperature-and/or composition- dependent, with temperature de-pendence based on a polynomial, piecewise-linear, or piecewise-polynomial function and individual component properties either de need by you or computed via kinetic theory .The Materials panel will show the properties that need to be de need for the active physical models. Note that, if any property you de ne requires the energy equation to be solved (e.g., ideal gas law for density, temperature-dependent pro le for viscosity), FLUENT will automatically activate the energy equation for you. You will then need to de ne thermal boundary conditions and other parameters yourself. Boundary conditions specify the thermal variables on the boundaries of your physical model. They are, therefore, a critical component of your FLUENT simulations and it is important that they are specified appropriately

The boundary types available in FLUENT are classified as follows:

- Flow inlet and exit boundaries: pressure inlet, velocity inlet, mass how inlet, inlet vent, intake fan, pressure outlet, pressure far- field, out how, outlet vent, exhaust fan Wall, repeating, and pole boundaries: wall, symmetry, periodic, axis Internal cell zones: fluid, solid (porous is a type of fluid zone).
- Internal face boundaries: fan, radiator, porous jump, wall, interior (The internal face boundary conditions are de need on cell faces, which means that they do not have a thickness and they provide a means of introducing a step change in how properties. These boundary conditions are used to implement physical models representing fans, thin porous membranes, and radiators.

*A. Pressure Distribution Analysis of Helium Recovery Tank during Operating Conditions:*

*1) Boundary Conditions:*

- Inlet Pressure: 0.5 bar.
- Outlet Pressure: 0.402 bar.
- Tank Internal Pressure: 0.40 – 0.48 bar.
- Temperature: 300 k.
- Valve Type: No slip.

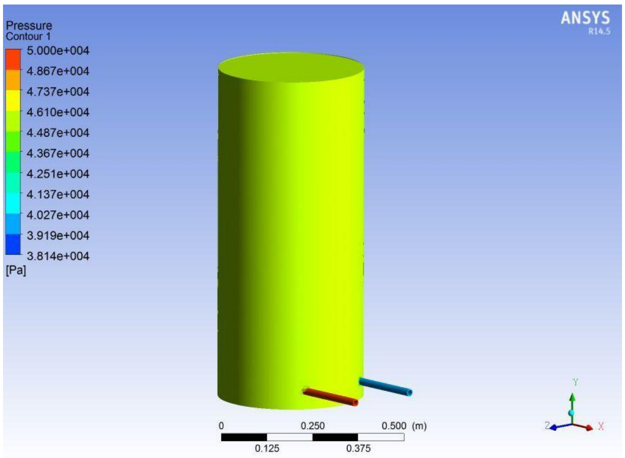

Fig. 4: CFD Analysis of Metal Tank at 0.5 bar

*2) Boundary Conditions:*

- Inlet Pressure: 0.6 bar.
- Outlet Pressure: 0.495 bar.
- Tank Internal Pressure: 0.49 – 0.58 bar.
- Temperature: 300 k.
- Valve Type: No slip.

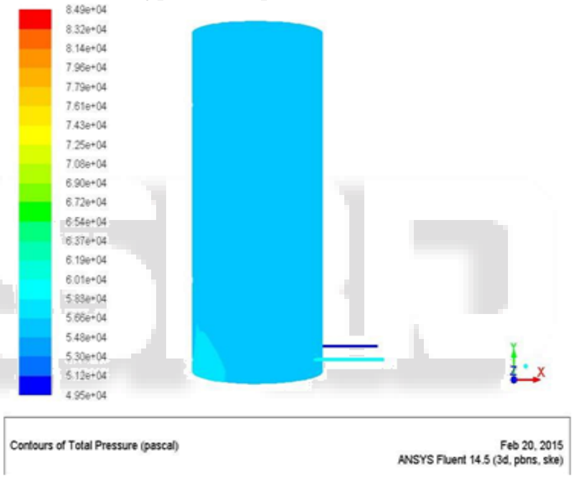

Fig. 5: CFD Analysis of Metal Tank at 0.6 bar

*3) Boundary Conditions:*

- Inlet Pressure: 0.7 bar.
- Outlet Pressure: 0.689 bar.
- Tank Internal Pressure: 0.68 – 0.69 bar.
- Temperature: 300 k.
- Valve Type: No slip.

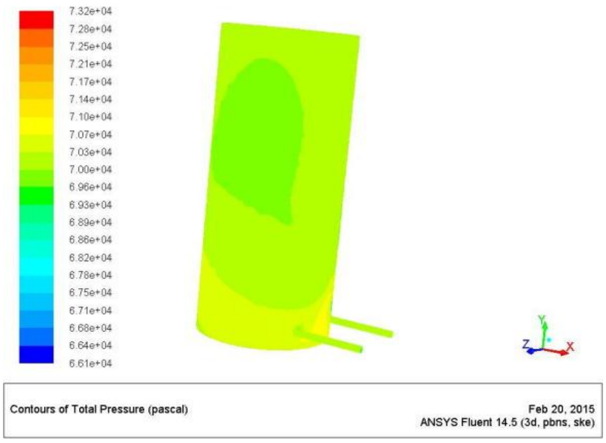

Fig. 6: CFD Analysis of Metal Tank at 0.7 bar

*4) Boundary Conditions:*
- Inlet Pressure: 0.8 bar.
- Outlet Pressure: 0.708 bar.
- Tank Internal Pressure: 0.7 – 0.73 bar.
- Temperature: 300 k.
- Valve Type: No slip.

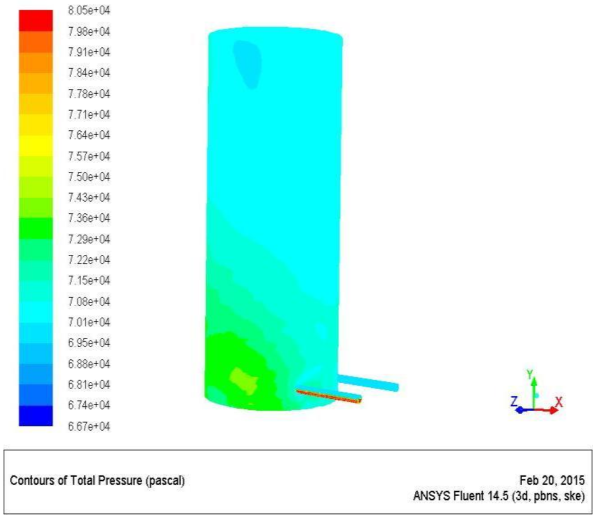


Fig. 7: CFD Analysis of Metal Tank at 0.8 bar

*B. Pressure Distribution Analysis of Heliumrecovery Tank during Extreme Conditions:*

*1) Boundary Conditions:*
- Inlet Pressure: 6 bar.
- Outlet Pressure: 5 bar.
- Tank Internal Pressure: 4.2–5.2 bar.
- Temperature: 300 k.
- Valve Type: No slip.

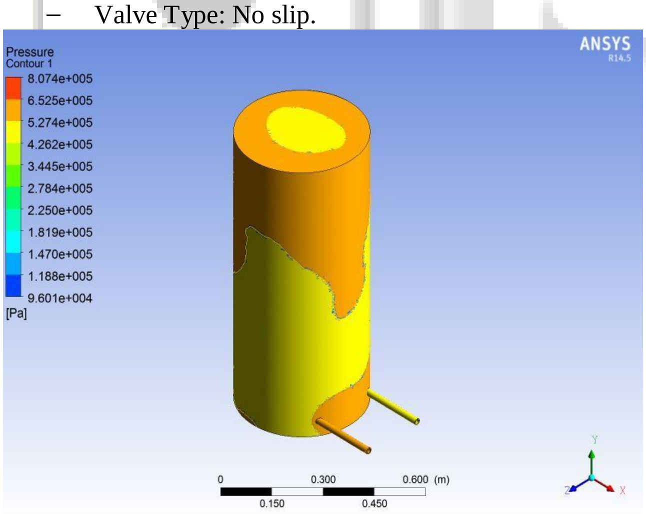


Fig. 8: CFD Analysis of Metal Tank at 6 bar

*2) Boundary Conditions:*
- Inlet Pressure: 10 bar.
- Outlet Pressure: 8 bar.
- Tank Internal Pressure: 7.3–8.9 bar.
- Temperature: 300 k.
- Valve Type: No slip.

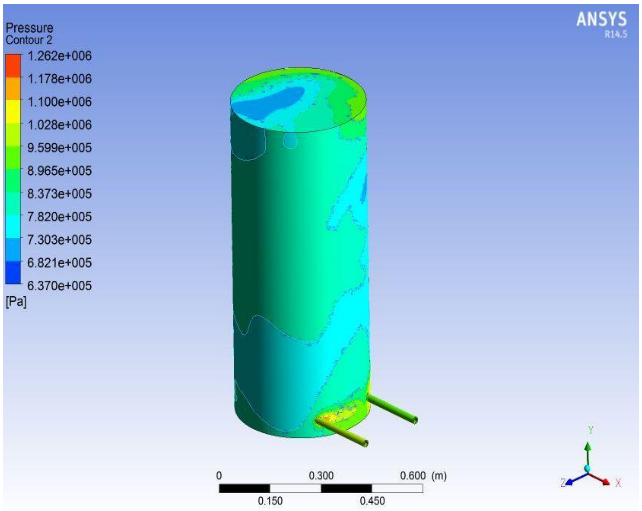


Fig. 9: CFD Analysis of Metal Tank at 10 bar

## IV. CONCLUSION

Testing of air conditioning components are carried helium during testing process, helium leakage occurring at the rubber bag present in the helium recovery system and process carried out in the testing line. This problem can be overcome by implementing a metallic tank, which would reduce the total helium consumption by 38% (approx) per month which cost saving about 99,000 INR per month and bag replacement cost can be eliminated completely. The testing process is altered by introducing an additional step of vacuumization after the helium is sucked back. On implementing such solutions the helium leakage will be minimised to a great extent and helium contamination can also be reduced in the testing environment.

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