Entropy Generation in Human Respiration System: a Review Paper

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***Abstract*— The irreversible processes involve heat and result in entropy generation, which tends to accumulate within the system. For example, friction heats up and slows down moving parts. The analysis of a number of natural processes can be facilitated by assuming that they are in fact reversible. These processes are called quasi-reversible.**

The respiratory system consists of two lungs, right and left, situated in the thorax and connected via their primary bronchi to the trachea and upper airway of the nose and mouth, The bronchi, or more generally the airways, then form a branching network which, for the most part, is a sequence of bifurcations. Each level of branching is called a generation, starting with the trachea as generation n=0, the primary bronchi, generation n=1, and so on. For a perfectly bifurcating system, there will be 2n airway tubes at generation n. For 0≤n≤16, the airways only conduct the gas flow in and out, they do not have any specializes apparatus for exchange of oxygen and carbon dioxide between air and blood. It is the conducting zone. For 17 ≤n≤19, there start to appear small air sacs, alveoli, on the airway walls. Alveoli are thin-walled and compliant with a rich capillary blood supply and are designed for gas exchange. These special airways are the respiratory bronchioles.

Keywords*— *quasi-reversible, bifurcations, entropy generation, viscoelasticity.

I. INTRODUCTION

The lungs main function is to help oxygen from the air we breathe that enters the red cells in the blood. Red blood cells then carry oxygen around the body to be used in the cells found in our body. The lungs also help the body to get rid of co2 gas when we breathe out. The lungs are like bellows: as they expand, air is suck in and, as they compress, co2 waste is pushed back out. The energy expand on breathing is used primarily in stretching the lung –chest system and thus causing air flow is normally amounts to one percent of the basal energy requirements of the body but rises substantially during exercise or illness. The respiratory pump is versatile, capable of increasing its output 25 times, from the normal resting level of about 6 litres (366 cubic inches) per minute to 150 litres per minutes in adults. Pressures within the lungs can be raised to 130 cm of water (about 1.8 pound per square inch).

Human breathes to get oxygen to their cells so that they can use oxygen to make cellular energy (ATP). Cells do this by completely breaking down glucose (sugar) into co2 and water. When human breathe in or inhale, their diaphragm contacts (tightens) and moves downward. This increases the space in your chest cavity, into which their lungs explain. The intercostals muscles between their ribs also help enlarge the chest cavity. The contract to pull their rib cage both upward and outward when they inhale.

A reversible process is defined as a process that can be reversed without leaving any trace on its surroundings. That implies that both system and surroundings are returned to their initial states at the end of the process. In some respects, the cardiac cycle might be considered a quasi-reversible process; in fact, myocytes turn chemical energy into mechanical energy, which is subsequently transformed into heat, but at the end of each cardiac cycle the heart tends to return to the initial volume and pressure conditions. However, part of the potential energy that is stored in chemical bonds ends up in less organized forms of energy that contribute to the entropy generation within the system. The possibility of minimizing the entropy production makes the heart move towards a quasi-reversible condition. In some respect, the cycles of the heart may be referred to as the coupled cycles that actually appear in dissipative structures arising in systems maintained far from thermodynamic equilibrium by energy flow.

A thermodynamic quantity representing the unavailability of a system thermal energy for conversion into mechanical work, often interpreted as the degree of disorder or randomness in the system. Entropy the measure of a system's thermal energy per unit temperature that is unavailable for doing useful work. Because work is obtained from ordered molecular motion, the amount of entropy is also a measure of the molecular disorder, or randomness of a system. The concept of entropy provides deep insight into the direction of spontaneous change for many every day phenomena. The static properties of the lungs have been explained by energy change considerations on the elasticity, but this article explains the elasticity if the lungs by entropy-change considerations.

It is the intention of the current work to use Computational Fluid Dynamics (CFD) to demonstrate and quantify the influence of asymmetry and bifurcation geometry on the pressure losses in branching airways, while recognizing that the ultimate flow distribution is largely determined by the particular placement of the bifurcation in the complex network of airways within the lung.

. For example, the flow distribution is often much more influenced by downstream lung volume or heterogeneous lung compliance than the asymmetry of a particular branch. Thus, a parametric analysis is performed where the morphologies and flow conditions are varied independently.

II. LITEARATURE REVIEW

Bejanet. al. [1] developed an analytical and graphical formulation of the constructed law of maximization of flow access in systems with heat and fluid flow irreversibility's and freedom to change configuration. The flow was assumed point to volume and point to area of the system. They have presented the contractual law in the graphical form and generation of new structure.

Dendrites flow structures dominate the design of natural and engineered flow systems, especially in thermal and fluid systems. The starting point is the optimization of the shape of each elemental area or volume, such that the length of the flow path housed by the element is minimized. Proceeding toward larger and more complex structures – from el flow structure developed in the nature Lorentz et al. [2]

David et.al. [3] stated that The effect of lung morphology on the heterogeneity of regional ventilation and particle deposition in the bronchial airways is studied using Herzfeld's regular-asymmetric lung model. Flow distribution among the airways is calculated by solving the whole tree network, assuming laminar flow hydrodynamic resistances without accounting for gravitationally enhanced preferential air flow distribution. It is shown that the fractal dimensions that characterize the morphological properties and the physiological processes are similar, suggesting that all are related and stem from a common underlying attribute—the lung morphology. The variation of particle deposition in the lung, as well as the variation of ventilation and morphological attributes, increases moderately with the lung tree asymmetry.

The contribution introduces an airway scaling procedure, which assumes (a) a fractal anatomy of the human lung and (b) a generation-related variability of bronchial morph metry in a chaotic fashion. Basic scaling of the branching system was conducted by application of an inverse power-law including the fractional dimension of the anatomic object. Simulation of intra subject diversity of the measurements, on the other side, was realized by using a normalized and repeatedly corrected variant of the logistic equation primarily introduced by Verhulst. Two morph metric data sets were theoretically approximated with the help of the scaling procedure, thereby assuming a morph metric diversity covered by a 60%-range – from American association for science & technology Robert et.al.[4]

Liua et.al. [5] developed the inspiratory flow characteristics in a three-generation lung airway have been numerically investigated using a control volume method to solve the fully three-dimensional laminar Navier–Stokes equations. The three-generation airway is extracted from the fifth to seventh branches of the model of Weibel with in- plane and 901 off-plane configurations. Computations are carried out in the Reynolds number range of 200–1600, corresponding to mouth-air breathing rates ranging from 0.27 to 2.16 l/s, or an average height of a man breathing from quiet to vigorous state. Particular attention is paid to establishing relations between the Reynolds number and the overall flow characteristics, including flow patterns and pressure drop. The numerically determined behaviour of $Re^{-0.61}$ assuming the airways to be approximated by two-dimensional channels.

Chang et.al. [6] analysed A thorough analysis of aerosol particle deposition in the human lung requires the knowledge of the distribution of inspired air at respiration. Ventilation distributions were determined under different gravitational force conditions. A larger gravity leads to a greater non uniformity of ventilation between the upper and lower lobes of the lung. When a different gas was inspired instead of air, a preferential distribution of ventilation to the upper lobes was found if the density of the inspired gas was greater than that of the air.

JILL et.al. [7] stated Although the lung is structurally complex, it is suitable for morphometric analysis of the structural determinants of lung function in health and disease. Analysis of the organized branching airways has been problematic because of the need to identify and classify airways before structural characteristics of different- order branches can be determined. Airway casts have been used to identify relationships between branches, measure some structural features, and develop mathematical models that describe simply the relationships between generations. We describe a new approach using tissue sections which combines the classification of airways into Strahler order (SO) with tissue structural analysis. Lung-tissue sections are prepared, and outer (OD) and inner (ID) diameters are determined over a wide range of airways. The line equation relating log OD vs. SO is determined using measured values for SO1 (terminal bronchioles) and SO8 (first branch bronchi). Mean ODs can then be calculated for each of the other SO groups, and measurements can be classified.

DONGYOUB et.al. [8] described a flexible mathematical model of an asymmetric bronchial airway bifurcation is presented. The bifurcation structure is automatically determined after the user specifies geometric parameters: radius of parent air-way, radii of daughter airways, radii of curvature of the daughter branchiopods, bifurcation angles, and radius of curvature of carina ridge. Detailed shape in the region where the three airways merge is defined by several explicit functions and can be changed with ease in accordance with observed lung structure

Alicia et.al. [9] stated Computational Fluid Dynamics simulations of inspiratory airflow in asymmetric bifurcations have been performed in order to determine the influence of the asymmetry and Reynolds number on pressure losses over a physiologically relevant range for pulmonary airways; thus, the results of this work can contribute to the understanding of respiratory ventilation in health and in disease. A key a priori insight to the design of the study is that the flow distribution in respiratory bifurcations can be largely independent of the local losses; and therefore, is predetermined by the boundary conditions in these calculations. The results, presented in the form of pressure loss coefficients, indicate that asymmetry and downstream conditions are significant for severe restrictions and laminar fowl; but are relatively insignificant for turbulent flow conditions and for flow through the healthy branch.

C. G. Caro et.al. [10] developed Swirling flow associated with non-planar arterial geometry encourages interest in flowing larger human bronchial airways, where bifurcations are planar but consecutive bifurcation planes rotate by an angle (φ)of ca.90°. Steady 'inspiratory' flow has been investigated in a two-generation symmetrically bifurcating human bronchial airway model by studying reddening by acid vapour of a litmus-containing coating as an approximate indicator of relative local wall shear (Sw). The inlet tube Reynolds number (Reit) was 600 or 1800; the branching angle (θ) was 32.5° at first generation and 32.5° or 55° at second generation; φ was 0° or 90° between first and second generations; second-generation daughter tube volume flow rates were the same. Inspiratory flow in larger human bronchial airways is expected to be asymmetric and swirling, with implications for all transport processes including those of particles.

Min-Yeong et.al. [11] stated Characteristics of pressure loss (DP) in human lung airways were numerically investigated using a realistic model bifurcation. Flow equations were numerically solved for the steady inspiratory condition with the tube length, the branching angle and flow velocity being varied over a wide range. In general, the DP co-efficient K showed a power-law dependence on Reynolds number (Re) and length-to-diameter ratio with a different exponent for ReZ100 than for Reo100. The effect of different branching angles on pressure loss was very weak in the smooth- branching airways.

Bahmanet.al. [12] analyzed practical deposition in symmetric bifurcation airways due to inertial impaction was studied numerically for inspiratory flows. Three-dimensional bifurcation models were constructed. The models had different parent and daughter diameters comparable to the airway generation 3-6 of the human lung. Airflow fields in the models were obtained by a finite-element method for different Reynolds number under parabolic and uniform inlet velocity conditions. The calculated flow filed data were used to simulate particle deposition. Based on calculated deposition results, empirical equations were derived for particle deposition efficiency as a function of non-dimensional parameters of stokes number, Reynolds number, and bifurcation angle for a parabolic or a uniform flow.

P. Nithiarasu et.al. [13] states Air flow through a human upper airway has been carried out using a realistic geometry. In addition to explaining the anatomy, problems and importance of patient-specific study of human upper airways, this article also presents some qualitative and quantitative simulation results, As expected, the shear pressure forces are large in or pharynx and laryngopharynx, where the flow passage is narrow. This clearly indicates that these locations should be the focus of any study aimed at understanding the human upper airway collapse in a patient- specific manner.

Srivastava et.al. [14] work on the steady motion of incompressible fluid through a curved tube of circular cross-section is extended. A method using Fourier-series development with respect to the polar angle in the plane of cross-section is formulated and the resulting coupled non-linear equations solved numerically. This theory fill a large part of the gap in existing knowledge of secondary flow patterns, which lies in the upper range of Reynolds number for which flow is laminar. This range is of particular interest in the investigation of the cardiovascular system.

Andrew et.al. [15] states two-phase flow through a rigid curved tube in which a fluid core is surrounded by a film of a second, immiscible fluid, surface tension drives the system towards a configuration in which the film thickness tends to zero on the inner wall of the bend. In the present work he demonstrates that the presence of steady states in which the film thickness remains finite. Analysis of the bifurcation model reveals that the bifurcation structure arises from a perturbation of the translation degeneracy of the interface in a straight tube.

III. EXPERIMENTAL DETAILS

The airflow through the lungs is governed by the Navier- Stokes equation, and the flow in any airway can be characterized by the non-dimensional Reynolds number, (Re)

$$R_e = \frac{\rho V D}{\mu} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where ρ and μ represent the air's density and viscosity, respectively; V is the mean velocity, and D is the diameter of the airway of interest. The air is assumed to have constant properties: density $\rho=1.225$ kg/m^3 and viscosity $\mu=1.7894\times10^{-5}$ kg/s m. In the current work, the reference Reynolds number is calculated using conditions at the inlet of the parent airway.

$$R_e = \frac{\rho V D}{\mu}$$

$$R_e = \frac{1.225\times7.69\times0.018}{(1.7894\times10^{-5})}$$

$$R_e = 9476.05343$$

Hence the flow is turbulent

Here f is a friction factor whose value depends on the flow regime and Reynolds number Re. For laminar, fully developed flow, f is analytically determined:

$$f = \frac{64}{R_e} \quad \text{when } R_e<2000 \text{-----------------------------------} (2)$$

For turbulent flow, f is calculated from the Blasiuscorrelation:

$$f = \frac{0.316}{R_e^{0.25}} \quad \text{When } R_e \geq 2000 \text{ ------------------------} (3)$$

Generation 1-4 Re is turbulent flow because where Re ≥ 2000

$$f = \frac{0.316}{9476.05343^{0.25}}$$

$$f = 0.03202803$$

Generation 5-23 is Laminar flow because where Re < 2000

$$f = \frac{16}{R_e}$$

$$f = \frac{16}{1883.29203} \text{---------------------} (4)$$

$$f = 0.0084938$$

Values of K were computed for the reference geometry at various flow velocities and daughter lengths, and a best-fit correlation was sought versus Re and geometric parameter L/d_1. All computed K values for $L \leq 10d_1$ fit the following correlations excellently .

$$K \propto R_e^{-\frac{1}{2}} \left(\frac{L}{d_1}\right)^{\frac{1}{2}} \qquad R_e \geq 100 \quad (5)$$

$$K \propto R_e^{-1} \left(\frac{L}{d_1}\right)^{3/4} \qquad R_e < 100 \text{ ---------------------- } (6)$$

Our numerical results for the bifurcating tube show very weak dependence of K on branching angle. Also a best-fit correlation for K that considers Re, L/d and θ can be obtained as follows:

$$K \propto R_e^{-\frac{1}{2}} \left(\frac{L}{d_1}\right)^{\frac{1}{2}} \theta^{\frac{1}{20}} \qquad \text{............} \quad (7)$$

This correlation is valid for a short bifurcating tube in laminar flow where Re ≥100, L ≤ 10d1 and d_1/d_0 =0.8.

Generation 1-11 $R_e \geq 100$ When $\theta = 70^0$

For, generation 1,

$$k = (9478.17216)^{-\frac{1}{2}} (6.66667)^{\frac{1}{2}} (70)^{\frac{1}{20}}$$
$$k = 0.03278012$$

Generation 12-23 $R_e < 100$ When $\theta = 70^0$

For generation 12,

$$k = (96.616825)^{-1} (4.58824)^{\frac{3}{4}} (70)^{\frac{1}{20}}$$
$$k = 0.040105134$$

Generation 1-11 $R_e \geq 100$ When $\theta = 90^0$

For generation 1,

$$k = (9478.17216)^{-\frac{1}{2}} (6.66667)^{\frac{1}{2}} (90)^{\frac{1}{20}}$$
$$k = 0.0331503$$

Generation 12-23 $R_e < 100$ When $\theta = 90^0$

For generation 12,

$$k = (96.616825)^{-1} (4.58824)^{\frac{3}{4}} (90)^{\frac{1}{20}}$$
$$k = 0.0406344$$

Generation 1-11 $R_e \geq 100$ When $\theta = 130^0$

For generation 1,

$$k = (9478.17216)^{-\frac{1}{2}} (6.66667)^{\frac{1}{2}} (130)^{\frac{1}{20}}$$
$$k = 0.03382771$$

Generation 12-23 $R_e < 100$ When $\theta = 130^0$

For generation 12,

$$k = (96.616825)^{-1} (4.58824)^{\frac{3}{4}} (130)^{\frac{1}{20}}$$
$$k = 0.0413884$$

Minor Loss Depended on angle

Generation 1-11 $R_e \geq 100$ When $\theta = 70^0$

$$k \times \left(\frac{v^2}{2g}\right) = 0.098801655$$

Generation 12-23 $R_e < 100$ When $\theta = 70^0$

$$k \times \left(\frac{v^2}{2g}\right) = 0.005632707$$

Generation 1-11 $R_e \geq 100$ When $\theta = 90^0$

$$k \times \left(\frac{v^2}{2g}\right) = 0.099917328$$

Generation 12-23 $R_e < 100$ When $\theta = 90^0$

$$k \times \left(\frac{v^2}{2g}\right) = 0.005707038$$

Generation 1-11 $R_e \geq 100$ When $\theta = 130^0$

$$k \times \left(\frac{v^2}{2g}\right) = 0.101959152$$

Generation 12-23 $R_e < 100$ When $\theta = 130^0$

$$k \times \left(\frac{v^2}{2g}\right) = 0.00581294$$

Frictional Loss :-

$$\frac{4flv^2}{2gd} \quad \text{Where f=friction factor ------------- (8)}$$

l= length in m. v=velocity in m/sec

d=diameter in m.

$$= \frac{4 \times 0.03202803 \times 0.12 \times 7.69^2}{2 \times 9.81 \times 0.018}$$

=2.574261345m

Total loss = Frictional loss + Minor loss

= 2.574261345 + 0.98801655

= 2.57117358m

Pressure Loss

From Bernoulli's equation,

$$\left(\frac{p_1}{\rho_g}\right) + \left(\frac{\alpha v_1^2}{2g}\right) - \left(\frac{p_2}{\rho g}\right) - \left(\frac{\alpha v_2^2}{2g}\right) = h_f$$

$$\frac{1}{\rho g}(p_1 - p_2) = h + \alpha\left(\frac{v_2^2 - v_1^2}{2g}\right)$$

$$\Delta p = \left(h_f + \alpha\left(\frac{v_2^2 - v_1^2}{2g}\right)\right)\rho g$$

$$\Delta p = \left(2.013151135 + \left(\frac{13.97^2 - 7.69^2}{9.81}\right)\right) 1.225 \times 9.81$$

[α=1 for a blunt velocity profile]

$$\Delta p = 190.8229204\ kg/m^2$$

Entropy Generation

We know that,

Entropy , $\Delta s = \frac{\Delta Q}{T}$ ---------(10)

$= \frac{vA\Delta p}{T}$

$= \frac{8.33\times0.0001169\times190.8229205}{309}$

=0.000601349 J/k

IV. RESULTS AND DISCUSSIONS

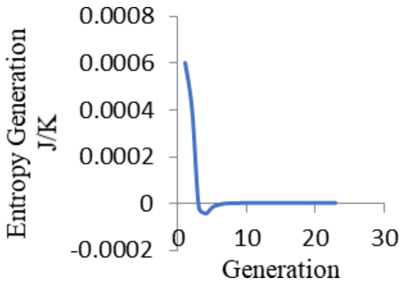

Figure 1 Entropy generation in each generation

The above graph says that the entropy of an isolated system during a process always increases, or in the limiting case of a reversible process remains constant (it never decreases). This is known as the increase of entropy principle. The entropy change of a system or its surroundings can be negative; but entropy generation cannot. But for an adiabatic reversible process the entropy generation is zero. A negative entropy means that "wasted" energy is transformed on work. Entropy remains constant in an adiabatic process which is also reversible. Now, since the process is adiabatic, so the heat transfer is zero and so the entropy change is zero through heat transfer. Here when generation slowly increases, entropy generation gradually decreases. At the stage of this process entropy generation is const. Entropy generation is caused by internal irreversibility thus depends on the nature of path followed during a process.

Total entropy change = Entropy change of reversible process executed in corresponding states + Entropy generation.

V. FUTURE SCOPE

A. *Basis on diameters*

In this paper we use same diameters of bifurcations. so, we calculate the losses of bifurcation only basis of single bifurcation. But here in future if we work on each & every diameter of bifurcation then we would see some difference in losses which are we actually get. This process will obviously help next generation.

B. *Flow ability*

A steady flow can be uniform or non-uniform and similarly an unsteady flow can also be uniform or non-uniform. Flow pattern in the airway lumen strongly depends on the geometry of bifurcation, so a realistic geometry model is needed to attain realistic flow fields. Here the flow is uninformed flow. If the flow is uniform then the process would change. In future may be research on this paper.

C. *Vascularization*

The current literature reveals a surge of interest in bioinspired designs of flow architectures that promise superior properties, for example, distributed and high-density heat and mass transfer. Chief among the new architectures that are being proposed are the tree-shaped (dendritic) designs. A significant stimulus for this new direction is the emergence of constructer theory as a means to explain biological and geophysical design, and as a method for developing new concepts for engineered flow architectures. This growing research activity was reviewed most recently in Refs. [1-3] and is not reviewed again here. Tree-shaped flow structures have multiple scales that are distributed nonuniformly through the flow space.

No equilibrium thermodynamics and maximum entropy production in the Earth system:

The Earth system is maintained in a unique state far from thermodynamic equilibrium, as, for instance, reflected in the high concentration of reactive oxygen in the atmosphere. Entropy production is a general consequence of these processes and measures their degree of irreversibility. The proposed principle of maximum entropy production (MEP) states that systems are driven to steady states in which they produce entropy at the maximum possible rate given the prevailing constraints. Entropy production allow human to quantify an objective direction of Earth system change When a maximum in entropy production is reached, MEP implies that the Earth system reacts to perturbations primarily with negative feedbacks. In conclusion, this no equilibrium thermodynamic view of the Earth system shows great promise to establish a holistic description of the Earth as one system.

Three-dimensional computer modelling of the human upper respiratory tract:

Computer simulations of airflow and particle-transport phenomena within the human respiratory system have

important applications to aerosol therapy and inhalation toxicology. A detailed description of airway morphology is necessary for these simulations to accurately reflect conditions in vivo. Therefore, a three-dimensional (3D) physiologically realistic computer model of the human upper-respiratory tract (URT) has been developed. The final unified 3D computer model may have significant applications to aerosol medicine and inhalation toxicology, and serve as a cornerstone for computer simulations of air flow and particle-transport processes in the human respiratory system.

Lifespan Entropy and Effect of Diet Composition and Caloric Restriction Diets:

The first and second laws of thermodynamic were applied to statistical databases on nutrition and human growth in order to estimate the entropy generation over the human lifespan. The calculations were performed for the cases of variation in the diet composition and calorie restriction diets; and results were compared to a base case in which lifespan entropy generation was found to be 11 404 kJ/K per kg of body mass, predicting a lifespan of 73.78 and 81.61 years for the average male and female individuals respectively. From the analysis of the results, it was found that changes of diet % of fat and carbohydrates do not have a significant impact on predicted lifespan, while the diet % of proteins have an important effect. Reduction of diet protein % to the minimum recommended in nutrition literature yields an average increase of 3.3 years on the predicted lifespan. Changes in the calorie content of the diet also have an important effect, yielding a % increase in lifespan equal or higher than the % reduction in the diet caloric content. This correlates well experimental data on small mammal and insects, in which lifespan has been increased by diet restriction.

Regenerative medicine for the respiratory system: Regenerative medicine (RM) is a new field of biomedical science that focuses on the regeneration of tissues and organs and the restoration of organ function. RM research regarding the respiratory system, including the trachea, the lung proper, and the diaphragm, has lagged behind. In this regard, this article briefly addresses the basics of RM and introduces the keyelements necessary for tissue regeneration, including (stem) cells, biomaterials, and extracellular matrices. In addition, the current status of the (clinical) application of RM to the respiratory system is discussed, and bottlenecks and recent approaches are identified.

Sequencing and Analysis of Globally Obtained Human Respiratory Syncytial Virus A and B Genomes:

Human respiratory syncytial virus (RSV) is the leading cause of respiratory tract infections in children globally, with nearly all children experiencing at least one infection by the age of genotyping, but relatively few whole genome sequences are available for RSV. The goal of our study was to sequence the genomes of RSV strains collected from multiple countries to two. Partial sequencing of the attachment glycoprotein gene is conducted routinely for further understand the global diversity of RSV at a whole-genome level.

VI. CONCLUSION

Pressure loss coefficients have been provided for asymmetric lung bifurcations over a physiological relevant range of incoming Reynolds number, the diameter ratio of parent to daughter, and the flow ratio. The flow ratio was prescribed to account for the fact that individual bifurcations are part of complex lung airway networks.

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