ME 329: Failure Analysis of a wine storage tank

A cylindrical wine storage container, of dimensions shown in the attachment, is filled to the top with a fluid of density, ρ=1.94slugs/ft^3 or 997kg/m^3 (recall, g=32.2ft/s^2). The tank is fitted with an access door at the base of the cylindrical tank. This access door (referred to as a man-way) closes against a cylindrical protrusion from the main body of the tank and is designed to be flush with the bottom of the tank. The access door swings on a pivot to allow easy clean-out when the tank is empty. The access door is attached to the swing arm through a socket joint at the center of the door, midway along the swing-arm. This joint allows the cover to pivot to allow better seal against a cylindrical rim. The center location of that socket also assures that the cover is center-loaded through the swing arm. A single ¾-10 UNC bolt made of steel provides closure force on the right side of the swing arm. This is accomplished by tightening a hand-wheel (D=11") made from brass and threaded to fit over the single UNC bolt. A gasket seals the door against the cylindrical opening that projects outward from the storage tank. Drawings and pictures are included on pages 4 and 5. During operation, the tank door is closed and tightened. There are no specifications on how tightly the door should be closed. As the tank is filled, a worker monitors the door. If the door leaks, the worker, who stands in front of the door, tightens the seal by turning the hand-wheel clockwise. After some 20 years of use, the tank was being filled. The door had a history of leaking and this time was no different. A worker was hand tightening the hand-wheel when the threads stripped and the door burst open. A jet of fluid hit the worker and pushed him some 40' until impact with the wall of a building. The worker was severely injured. Your task is to assess the design of the door and to also calculate the exit velocity of the wine after the door opens. You will need to draw free body diagrams of the door, the swing arm, and the bolt/hand-wheel. You will also have to sort out the exit speed of the jet of fluid.

Write a report that includes all of your FBDs, your force analysis on the door, the swing arm, the bolt and the hand-wheel. You will do this for the condition of a full tank (filled to the top of the tank cylinder.

1. You must calculate the force that must be applied to the door to keep the door from leaking. (You can assume a gasket pressure of 3 times the max fluid pressure on the door). Keep in mind that the pressure varies with height. You must consider all of the forces acting on the door to determine the net overall force that must be applied to the door through the center-socket.
2. Determine the bolt load required to achieve this force.
3. Find the torque that must be applied to the hand-wheel to achieve this bolt load.
4. Using the dimensions of the hand wheel, what forces must be applied to the hand wheel to achieve this torque?
5. Is it reasonable to presume that a 250lb person can apply such a load?

6. Create a representative hand-sketch of the hand-wheel and bolt…then create a CAD model of a simplified version of this.
7. Run a Fusion FEA of the bolt/nut combo for the loads you applied. What are the thread stresses, and what is the factor of safety if the hand-wheel is made from Brass.(which brass?)
8. Write a report that includes all drawings, FBDs, hand-sketches, equations, and calculations. Include your FEA results and comment on those results.
9. Finally, comment on the pros and cons of the design. Was such a failure to be expected?

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