Application of a Polymeric Desiccant

For Technical Advisor overlook

San José State University
Charles W. Davidson College of Engineering
Mate 198A – Senior Design Project

Section 1
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1. Introduction

Standards for properly storing and keeping electronics exist mainly by IPC and JEDEC with their specified standards of J-STD-033 for surface mounted devices. However, the aforementioned standard, J-STD-033, loosely defines what constitutes as a desiccant. Moreover, the standard refers to the outdated military specifications, MIL-D 3464 written in 1967, for further reference to properly package, ship, and store electronic devices. These confusing rhetoric's, from what is expected to be new modern industry standards, alongside references to old specifications showcase a need for updates for new products that have entered the market that do not pertain to any of these antique guidelines. And so, this allows commercial grade desiccants to stretch the truth of their respective products and use words that prove contradictory in terms as they take on the lion share of the packaging market.

In this project, the goal is to provide data and product demonstration of the Steel Camel absorbing desiccant in comparison with other commercial grade adsorbing desiccants. Which include the likes of commonly used desiccants like silica gel, montmorillonite clay, and bentonite clay. Some of the constraints that pertain to this project and that will be further addressed are the humidity chamber box parameters, how the relative humidity is checked, the maintenance of temperature in the chamber, and the margin of error of the measurement inaccuracy of the equipment to check humidity and temperature.

2. Technical Background

The current outlook of the desiccant market is segmented into a small group with some of them much more used than others. Those notable desiccants being silica gel, zeolite (molecular sieves), activated alumina, activated charcoal, calcium oxides, calcium sulfates, montmorillonite clay, bentonite clay, and other desiccants [1]. More polymeric based desiccants like Steel Camel's are not widely used and are not widely manufactured to the same degree as the aforementioned ceramic-based desiccant. Though polymeric based desiccants have been taken some level of study on both the academia field [2] and governmental research [3] much of them do not enter the commercial market. Moreover, designs of polymeric based desiccants in woven fabric containers have been successfully patented over the years [4] but again do not enter the commercial market. Moreover, the commercial market is segmented into two main sectors of the food and drug, and other packaging (both electronic and non-electronic materials). Pharmaceutical and food require regulations administered by governmental agencies like the FDA. And due to extensive testing of silicon's chemical properties, its non-corrosivity and non-toxicity allowed for approval in the food and drug packaging which gave the reasoning behind its large usage [5].

For more in-depth of the various popular desiccants such as silica gel, zeolite, clay, these are all ceramic materials that are rather amorphous and porous. These pores are microscopic but are interconnected on the surface allowing for water to be retained through capillary condensation [6]. In the cases such as montmorillonite clay and bentonite clay, the material interactions between water and the clay particles allow for the surface interactions of the various bonding of; hydrogen bonding, ion-dipole, dipole-dipole, and van der Walls [7]. In all ceramic based desiccants, they can be reactivated without changing inherently the molecular structure or mechanical properties of the material which is why ceramic based desiccants can be "reactivated" by heating it under a heat source to release the water molecules retained in a given desiccant. Though in the case of polymeric based desiccants, reactivation is not an option as the monomers in the polymer chain can be broken down by heat.

3. Feasibility Study Plan

Overall, within the fall semester, an outline of the activities pursued within the course can be seen in Figure 1. The initial outline of the project indicates the initial start day, and the following days thereafter indicate correspondence into acquiring the desiccant materials. Research of the desiccants began shortly after seeing the standards, papers, and characteristic properties of the various desiccants was researched shortly after. Construction and thereafter further chamber optimization occurred after procuring the desiccants as input from other students and Professor Richard Chung accounted for multiple changes with the chamber. Official testing there after and simultaneous data analysis shortly thereafter and are still being done up to this point.

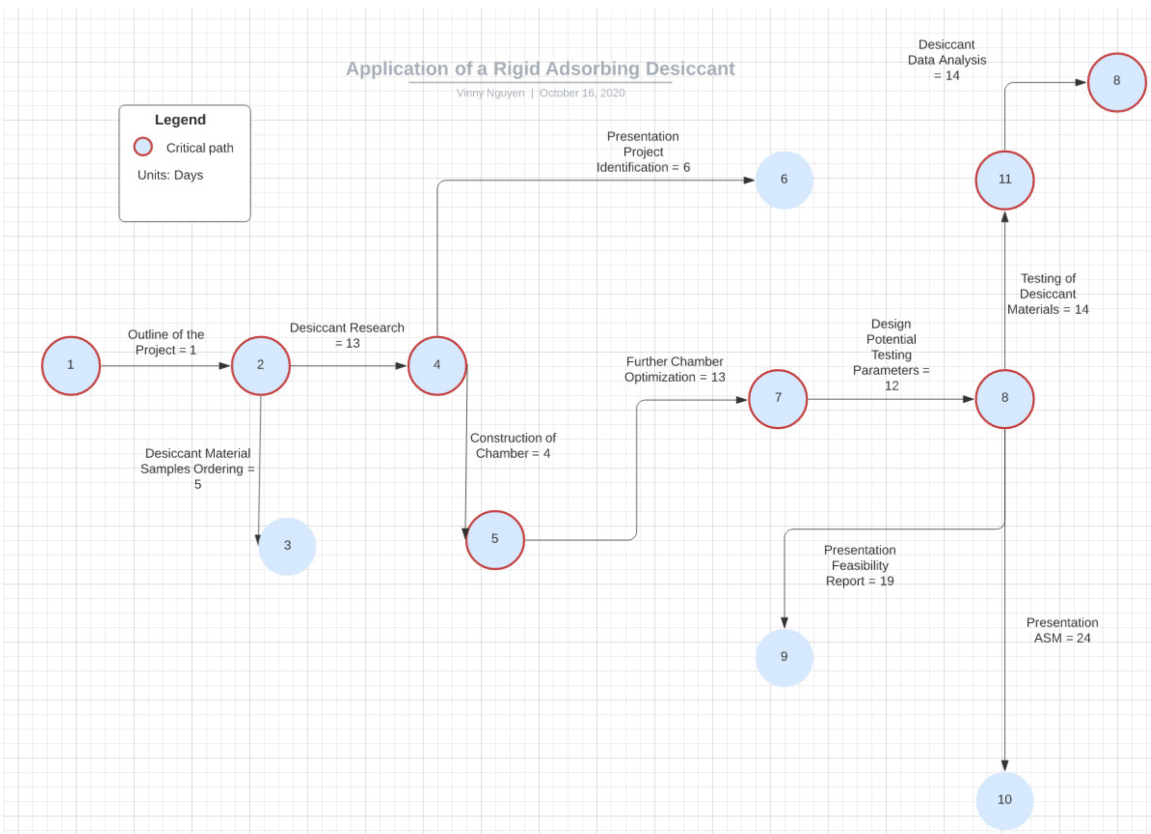

Figure 1. Network diagram of all activity blocks of the project

Table 1 outlines the approximate times of which the earliest to latest starting and finishing times occurred to indicate the fastest path and latest paths for milestone completion for the semester. 68 days indicate the earliest in which all milestones were to be started and 74 days indicate the latest times in which those milestones could be met. In actual meeting these milestones occurred in a time scale in between those two.

Table 1. Calculation of the earliest-latest starting and finishing times for each of the activities

TASK TITLE	START DATE	DUE DATE	DURATION IN DAYS	Early Start	Late Start
Project Outline	09/11/20	09/12/20	1	1	1
Desiccant Research	09/13/20	09/26/20	13	2	6
Construction of Chamber	09/24/20	09/28/20	4	12	16
Further Chamber Optimization	09/28/20	10/11/20	13	16	23
Design Potential Testing Parameters	10/11/20	10/23/20	12	28	35
Preliminary Tests with Chamber	10/23/20	10/30/20	7	41	47
Testing of Desiccant Materials	10/30/20	11/20/20	21	48	55
Data Analysis of Testing	11/20/20	12/04/20	14	68	74

4. Feasibility Study Results

All of the aforementioned milestones were completed and met within the given semester without much issues or concerns. Though it's to be clarified that both testing and data analysis are still being done during the winter break. Most of the challenges that occurred were surrounded more so with the humidity chamber and diagnosing reasoning between irregularities of humidity levels. Humidity level irregularities were determined to be due to the hygrometer that was measuring the approximate levels and not due to the chamber itself. The environment in which the humidity chamber testing was done also played a factor in affecting humidity levels. As normal humidity levels where the chamber was housed had a relative humidity level of 50%.

Moreover, current experimental setup includes the usage of the aforementioned homemade humidity chamber built from Acrylic plexiglass (6 sheets measured at 10 x 10) from Tap Plastics and sealed with electrical tape in order to better retain humidity. A small humidifier unit is inside chamber as well and the mason jars to hold the desiccant inside with a hygrometer probe to measure the %relative humidity is in the chamber as well. Humidity card indicators are placed inside the chamber to further double check if readings are accurate. Temperature is contained between 22-24^{o}C in the humidity chamber, which is close to the recommended temperature to both Mil-D 3464 and J-STD-033.

Current tests involve water retention of various desiccants which entails measuring various desiccants at a set weight of 1 gram and introduce water to them until they are fully saturated or an excess of water is seen. These results can be seen in figure 2. Silica gel is seen to be able to hold 50% of its weight in water, montmorillonite clay holds about 136% of its weight, bentonite clay holds 157%. The Steel Camel desiccant was able hold 140x its weight in water.

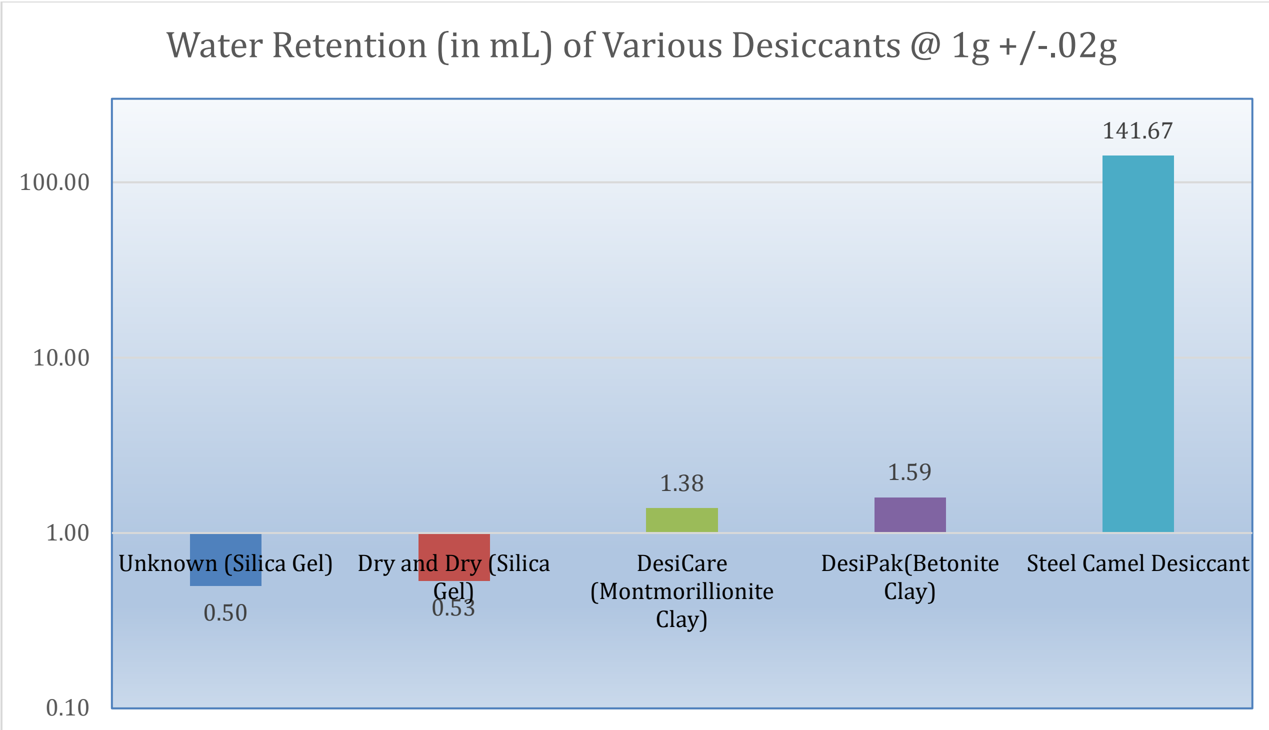

Figure 2. Water retention in milliliters of silica gel, montmorillonite clay, bentonite clay, and the steel camel desiccant at weighed out samples at 1 gram.

Another test is %RH over Time at a set weightage with its procedure outlined below and its results seen in figure 3. Preliminary results show how well both bentonite clay and steel camel to maintain its relative humidity over time much better than silica gel or montmorillonite. Though silica gel is shown to beat montmorillonite on the graph, its expected that montmorillonite will plateau and maintain a better relative humidity level than the silica gel. The procedure of the test can be seen below.

1. Weigh out a given desiccant to 50 grams.
2. Place the given desiccant inside the jar alongside a humidity indicator card (which is in the humidity chamber).
3. Activating the humidifier unit which dispenses water vapor into the system (increases the %RH).

4. Measure and record the %RH every 30 minutes for seven hours.

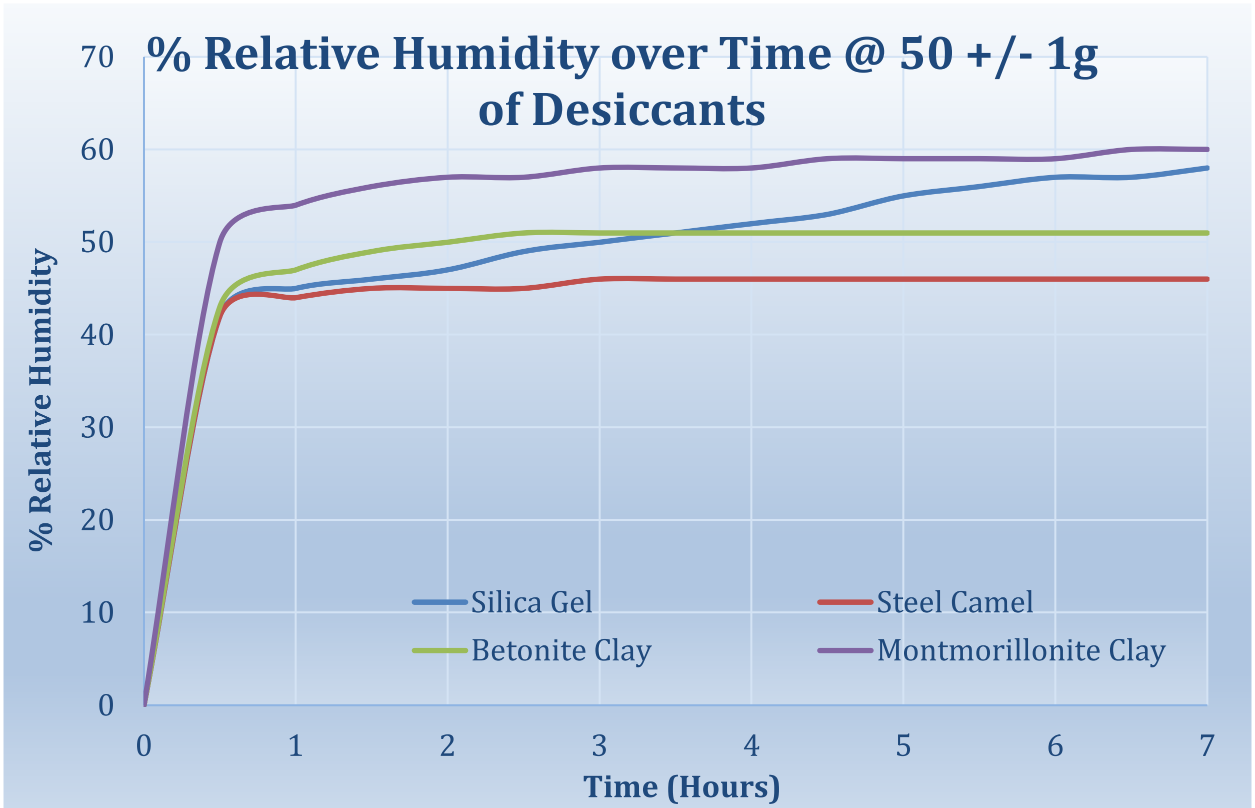

Figure 3. Percent relative humidity of silica gel, montmorillonite clay, bentonite clay, and the Steel Camel desiccant at weighed out samples at 50 grams recorded over a period of 7 hours.

The most recent and ongoing test can be seen in figure 4, measuring the volume of water vapor that is absorbed (for the time being, silica gel and bentonite clay) over a period of 13 hours. Preliminary tests indicate that bentonite clay has absorbs water vapor better than silica gel in an enclosed space.

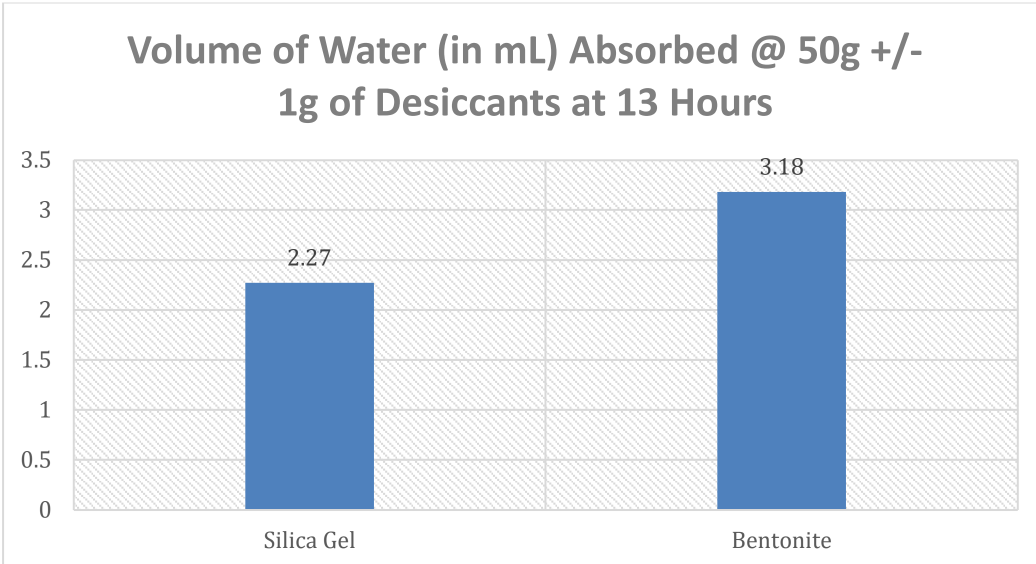

Figure 4. Volume of water vapor absorbed by silica gel and bentonite clay weighed out at 50 grams at a time of 13 hours.

With all current tests shown, its to be said that the project is very feasible and most likely will be completed on track in the second semester.

5. Broader Considerations

Some of concerns or broader considerations have been made into the lab procedures are that some level of standard operating procedures are necessary in the testing and the applications of the desiccants. As seen in figure 5, iodized salt and the Steel Camel desiccant looks similar, so proper procedures in order to ensure safety and laboratory related incidents do not occur like accidental indigestion.

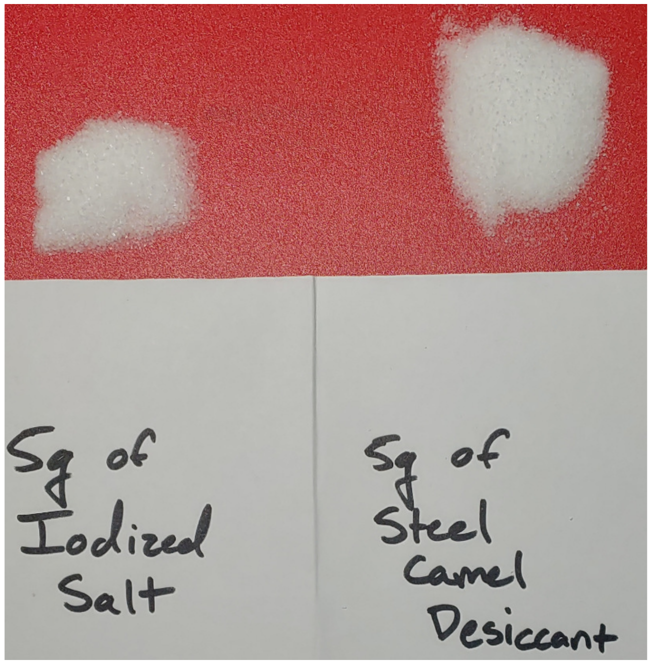

Figure 5. Surface similarities of iodized salt and steel camel Desiccants

Other considerations are for theorized tests that will be done in the future, for example how much moisture is released when the ceramic based desiccants are reactivated. This would involve usage of an oven or other heating elements which entails a hot surface. The procurement and safety procedures are then necessary to use such test. That said, other broader considerations include potentially requesting more desiccants as some desiccant's specimens might run low in volume and should not be reactivated as virgin material will better depict accuracy of data measurement.

The biggest consideration to be made is the material selection of the humidity chamber. As mentioned previously the chamber is made from an acrylic plexiglass sheets made from Tap Plastics. Though plexiglass has considerable water resistance and other chemical resistances, one of the biggest issues is its thickness and thereby temperature and humidity loss. The data sheet of the manufactured plexiglass lists the density as 1.20g/cm^3 [7] which is only .02 g/cm^3 than polycarbonate [8]. However, the sheets at TAP can only be extruded up to ¼ and ½ an inch for plexiglass and polycarbonate respectively. Figure 6 shows the initial humidity chamber, and showcases the chamber has a wall thickness of less than 6 cm.

Figure 6. Photo of the Acrylic Plexiglass humidity chamber with humidifier unit, hygrometer and containment units (mason jars) to hold the desiccants

Figure 7 shows the humidity chamber in actual use. No noticeable amount of water leaks out of the chamber even without the tape but the issue lies with the loss of humidity of the chamber. This is apparent due to some water vapor escaping the containment unit. Though polycarbonate is not significant better in chemical or mechanical properties that would pertain to this project, it is the only material TAP extrudes at a much higher thickness. Therefore, is a promising upgrade for the spring semester.

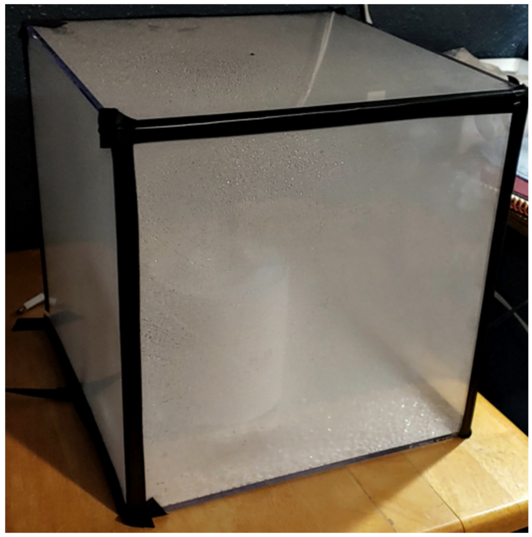

Figure 7. Photo of the Acrylic Plexiglass humidity chamber when in use

6. Plan and Scheduling (Timetable)

Similar to table 1, table 2 outlines the milestones for the second semester. As the preliminary setups have been made, the only big milestones left are the continued testing of the desiccant materials. Dates are tentative to change but will generally coincide with the months listed. That said, designing new potential testing parameters while testing of the desiccant materials will continue up until the chamber is optimized completely. The unforeseen second mandated state and county lockdowns as of December 14 will not affect any time schedules at all.

Table 2. Theorized timeline for the major tasks that are to be completed in the Spring Semester

TASK TITLE	START DATE	DUE DATE	DURATION IN DAYS
Design Potential Testing Parameters	12/11/2020	3/??/2021	??
Testing of Desiccant Materials	12/11/2020	2/??/2021	??
Further Chamber Optimization	1/??/2021	2/??/2021	??
Contd. Testing of Desiccant Materials	2/??/2021	4/??/????	??
Data Analysis of Testing	4/??/2021	5/??/2021	??

7. Summary and Conclusions

In summary, most safety considerations are the same as standard precautions working in any lab environment. Current ongoing tests will be continued and repeated to further prove replication and accuracy. Though preliminary results can be seen, a conclusive report of the results cannot be made with complete assurance. Future improvements of the humidity chamber will be made from the initial acrylic plexiglass into a thicker polycarbonate case as temperature loss and relative humidity loss are still some concerns. Other things like thinking and testing of new methodologies for new tests like amount of air that can be desiccated will be continued throughout the winter break and the spring semester as well. The project is on track to be completed by the end of the spring semester and no significant change in direction has been made at this point in time. Though the title from “Application of a Polymeric Desiccant” to “Application of Desiccants” will be made to better state that no bias was made in any area.

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