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IMPROVING STRATUS FORECASTING AT SAN FRANCISCO

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The intention of this paper is to show how a relatively small research project might have a major impact on the daily operations of a major airport, San Francisco International Airport (SFO). Before describing this project, it is necessary to understand some background information.

SFO has two parallel runways normally used for arriving aircraft. In order for two aircraft to land at the same time on the parallel runways, i.e., "side-by" operations, the pilot of an arriving aircraft must be able to see the other aircraft and the runways from about seven miles east of the airport. During "side-by" operations, the acceptance rate at SFO is between 55 and 60 aircraft per hour. If the pilots cannot see the other aircraft or the runways, SFO can use only one runway for arrivals, i.e., "in-trail" operations. During "in-trail" operations, the acceptance rate drops to between 32 and 36 aircraft per hour.

One of SFO's highest arrival demand rates is between 9:30 a.m. and noon, local time. Morning departures from the East Coast are arriving, as well as a large number of aircraft from Southern California.

During the late spring and summer months, low stratus clouds frequently spread into the San Francisco Bay area during the evening hours. These low clouds usually dissipate during the late morning, about the time of SFO's highest arrival demand rate. When the stratus covers the final approaches to SFO, pilots are not be able to see other aircraft or the airport. Therefore, SFO's acceptance rate drops to between 32 and 36 aircraft per hour. Once the stratus clears, the airports acceptance rate increases to between 55 and 60 aircraft per hour.

The FAA uses national ground delay programs to help keep the number of aircraft arriving at SFO equal to the airport's hourly acceptance rate. SFO-bound aircraft may be delayed all over the country if the FAA expects a low acceptance rate at SFO. Due to the high costs associated with fuel, operations, ground support, etc., it is much better to delay aircraft at their departure airports than to have them circling over the western U.S. How does the FAA forecast the acceptance rate at SFO? The FAA depends heavily on the forecasts generated by the Oakland Center Weather Service Unit (CWSU OAK), collocated with the FAA Air Route Traffic Control Center. Next to forecasting hazardous weather, the SFO terminal forecast is the most important forecast made by the CWSU OAK. If the forecast calls for "late" clearing of the stratus and it clears early, aircraft from all over the country will have taken unnecessary ground delays. If the forecast calls for an "early" clearing of the stratus and it dissipates late, aircraft will be in airborne holding patterns all over the western U.S. An accurate forecast allows the FAA to establish the correct ground delay program and has enormous economic importance to the airlines.

In 1986, the CWSU OAK began recording a verity of data related to the stratus in an effort to improve stratus forecasting. This information included: 14Z stratus base/amount/tops; various pressure gradients; times when the stratus decreased to scattered (SCT) and cleared around SFO; the general synoptic pattern; and any pertinent remarks. Analysis of the data indicated a good correlation between the stratus base, stratus thickness, and the time the stratus decreased to SCT. It seemed reasonable that the stratus thickness would have a good correlation. However, it was not expected that the stratus base would also have a good correlation. Additional analysis of the data showed that the general synoptic pattern was also related to the clearing time. During the summer of 1986, there was usually an upper ridge of high pressure located near the California coast. On days when an upper trough of low pressure was near the coast, the stratus usually cleared much later. However, by the end of the 1986 summer, there was an insufficient number of "trough" cases to allow a separate analysis of that data. Therefore, the "trough" cases were kept out of the final analysis.

Plotting the data in graphical form produced results shown in Figure 1. Isochrones (lines of constant time) are subjectively fit to the individual cases plotted. This graph was used in the summer of 1987 by both the CWSU and the WSFO SFO to help forecast the stratus. The time it took for the stratus to decrease to SCT is shown in hours and minutes after sunrise, since it is the time needed by the sun to burn off the stratus that must be considered. The time when the stratus decreases to SCT (instead of the time it took to clear) was used because analysis showed it to be a more conservative and useful figure. The FAA can usually expect "side-by" operations within 30 to 45 minutes after the stratus becomes SCT.

During the late spring and summer of 1987 and 1988, more data was recorded and the graphs were refined. By 1988, enough cases of an upper trough near the California coast were available for two graphs to be developed; one for a "ridge pattern" and one for a "trough pattern".

THE "RIDGE PATTERN" GRAPH...FIGURE 2...

As would be expected, this graph is similar to the original 1986 graph where the "trough pattern" data was omitted. This graph would be used much of the time when an upper ridge of high pressure is in the vicinity of the California coast and an anti-cyclonic flow pattern is over SFO. Simply find the base and thickness of the stratus at SFO at about 14Z, and then read the time it should take to become SCT in hours and minutes after sunrise. The stratus ceiling should be overcast (OVC) for the graph to work correctly. In some cases it was necessary to approximate the stratus base. Consider an observation of 10 SCT C16 OVC. The stratus base is not 010 or 016. The approximated stratus base would be about 014, since the lower layer is only SCT and the approximated base must be closer to the 016 OVC than the 010 SCT. If the observation had been C10 BKN 16 OVC the approximated stratus base would be about 012, that is, closer to the lower BKN layer (because most of the clouds are based there) than the higher OVC layer. A large amount of data was used to draw the ridge pattern graph. In most cases, it can be used with a fair amount of confidence. However, note that there are data sparse areas, and even in data rich areas, there are a few cases where the data simply do not fit well.

THE "TROUGH PATTERN" GRAPH...FIGURE 3...

This graph would be used when an upper trough of low pressure (long or short wave), or a cut-off low is near the California coast, and a cyclonic flow pattern is over SFO at 700-500 MB. A comparison of the two graphs shows that in the trough pattern, the time it takes the stratus to decrease to SCT is longer and more variable for any given base/thickness combination. The atmospheric instability associated with a trough probably causes this increased dissipation time and variability. Due to the increased variability and the limited number of cases available, the trough pattern graph should only be used for a first guess and with far more caution than the ridge pattern graph.

Both graphs show, as one would expect, that the thicker the stratus layer, the longer it takes to become SCT. However, the graphs also reveal an unexpected pattern; for stratus with a given thickness, there is more than one unique base height for which clearing is most rapid. The reason for this is not clear, but more research and data may help solve this and other questions. The CWSU will continue to collect data and study the stratus at SFO, and will continue to use these graphs to help forecast stratus dissipation.

In the future, advances in aircraft landing technology may make it possible to use side-by operations even if the approaches to an airport are obscured by low clouds. But for now, the summer stratus will continue to restrict landings at SFO. The FAA will continue to use ground delay programs to help mitigate this problem and improve the operations at SFO. The objective of this research project was to improve stratus forecasting and therefore aid the FAA in establishing the correct ground delay programs for SFO. It is felt by both the FAA and NWS personnel at the Oakland Air Route Traffic Control Center that these objectives were accomplished and that the operations at SFO have improved as a result.

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TIME FOR SUMMER ST CIG AT SFO TO BCM SCT
(HR:MIN AFTER SUNRISE)

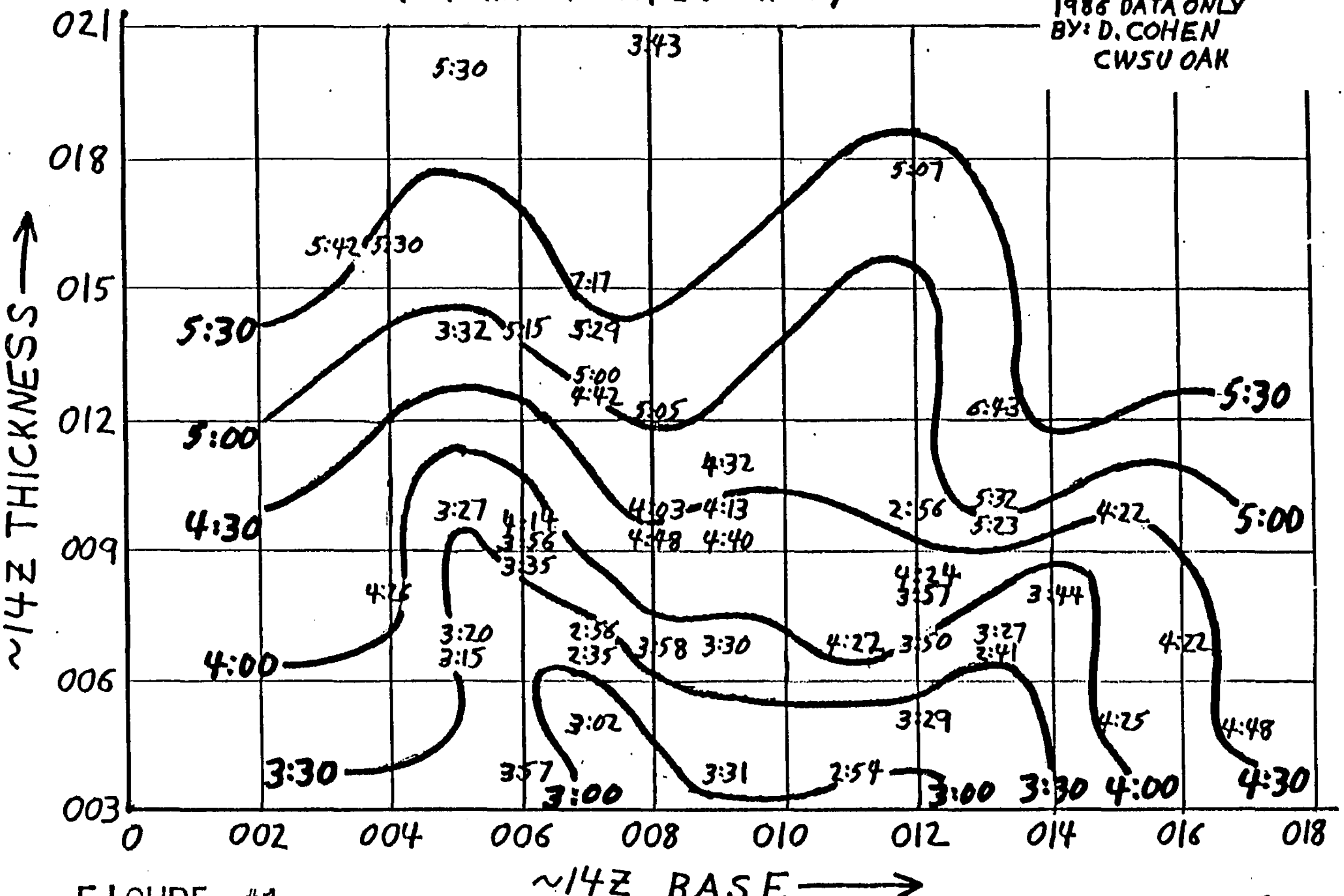

FIGURE #1

TIME FOR SFO STRATUS CEILING BECOME SCT..HR:MIN AFTER SUNRIS

RIDGE PATTERN...SUMMER 1986-88

BY: D. COHEN; CWSU OAK

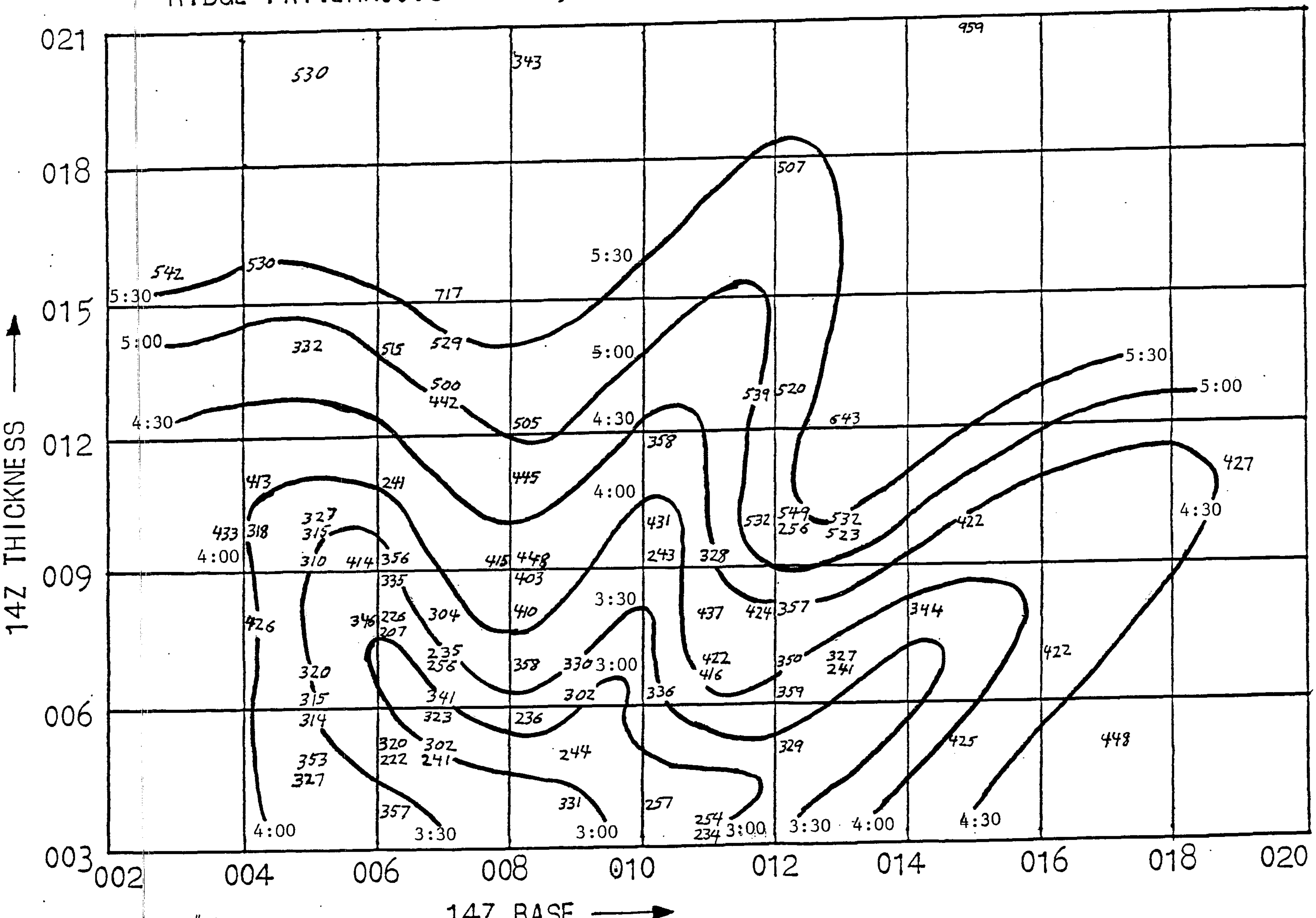

FIGURE #2

TIME FOR SFO STRATUS CEILIN 'O BECOME SCT..HR:MIN AFTER SUNRI

TROUGH PATTERN...SUMMER 1987-88

BY: D. COHEN; CWSU OAK

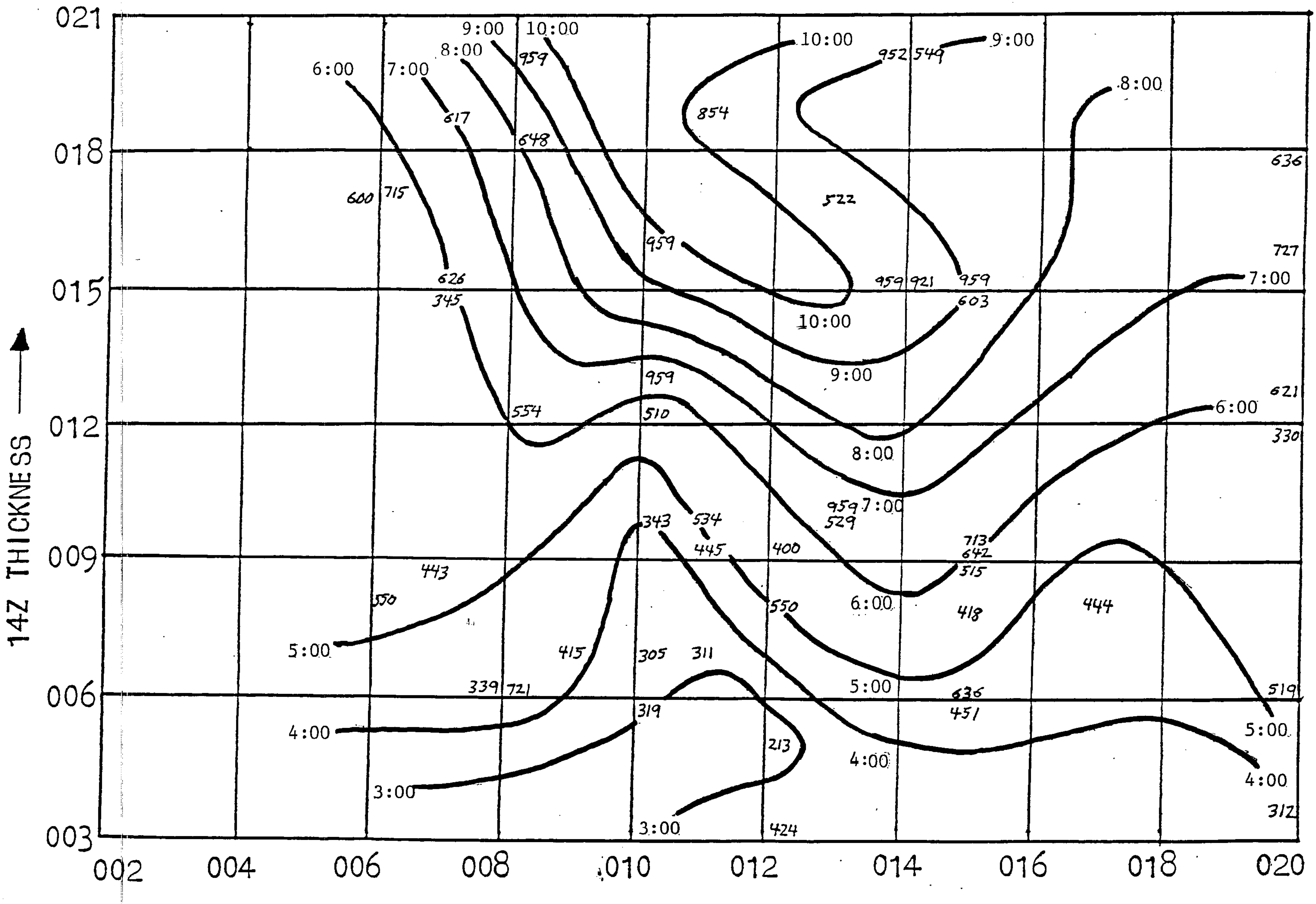

FIGURE #3