http://www.siranah.de/html/sail008g.htm

Celestial Navigation: Special Techniques

Chronometer Check with Celestial Observations

With celestial observations only a rough check of the chronometer can be achieved. The whole system of determining positions with celestial methods is based on the accurate knowledge of the UTC time.

Two different methods to check the chronometer can be used:

- a first method is based on calculated Altitudes and requires accurate knowledge of the position
- a second method does not require any knowledge on time or position and is based on lunar observations

Time from Position

The first method is based on calculating the rise and set times of celestial bodies for the known position and compare these with the chronometer time. The accuracy of this method is limited by how accurate the position is known and how accurate rise and set events can be observed. This is usually not better than 2 .. 5 minutes without using a sextant.

If a sextant is available, not only checks for rise and set times can be performed. The observed Altitude for an arbitrary time instant can be calculated. The sextant is set to this calculated observed (!) Altitude. Then the time when the celestial body is exactly on the calculated Altitude is compared with the chronometer time.
The accuracy of this method, when the position in know within 2 nautical miles and the conditions for sextant observations are good, will be better than 1 minute.

Time from Lunar Observations

The second method yielding both position and time is based on the fact that the moon is "moving" much faster along the sky than other celestial objects. The method for getting the correct time is based on the following:

- determine the position using the "incorrect" chronometer time with both the sun and the moon by elaborating two Lines-of-Position for each object. This will yield two positions: one "solar position" determined by solar observations and one "lunar position" determined by lunar observations. Ideally, when the chronometer time is correct and the observations are error free, these two positions will be identical.
- For each minute of chronometer error the "solar position" will be moved by about 15' of Longitude. For the same error, the "lunar position" is moved "only" by 14'5.
  This was already known in the 15th century: navigators could determine Latitude with some accuracy but they couldn't determine Longitude because they hadn't clocks nor accurate enough Ephemerides Data.

The Latitude difference due to changes in declination are ignored here. The resulting errors are much smaller than the inherent accuracy of this method.
For large chronometer errors, the "solar position" will differ considerable from the "lunar position" and both will be far away from the correct position. The time can be corrected by dividing the Longitude difference (expressed in minutes of arc) between the "lunar position" (LP) and "solar position" (SP) by the factor 0.5'/min.

This yields the chronometer error:

chronometer_error [min] = (LP_Longitude - SP_Longitude) * 2.0 [' * min/']

A positive chronometer error means that the chronometer time is leading UTC time (chronometer rate is too fast). Conversely, a negative chronometer error means that the chronometer time is lagging UTC time (chronometer rate too slow). With the chronometer error known, both positions can be corrected (moved) to obtain the correct position.

Also the correct time can be determined. The achievable accuracy depends on how accurate the celestial observations are performed. A realistic value for the accuracy of the chronometer time determined with lunar observations may be in the range of 10 .. 30 minutes. The accuracy of the positions obtained with such chronometer errors will be correspondingly!

Here is an **example** demonstrating the required calculations. The example is rather theoretical because two observations are done at the same time. This just improves clarity.

On 20th of March 2002 our true (but unknown) position is:

N 48° 12'0
E 011° 32'0

We observe the Sun and the Moon at 12:00:00 UTC and again at 15:00:00 UTC. However our chronometer has an error of 15 minutes and our observations were in fact done at 12:15:00 and 15:15:00 respectively. The observed Altitudes are:

UTC 12:15:00 15:15:00
Chronometer 12:00:00 15:00:00

Sun 40° 18'3 20° 22'8
Moon 37° 53'2 61° 23'7

If we enter the Nautical Almanac with 12:00:00 UTC and 15:00:00 UTC to determine the two positions: one with the two observations of the Sun ("solar position") the other with the two observations of the Moon ("lunar position") we first find the following Geographical Positions locations:

Chronometer 12:00:00 15:00:00
GHA Dec GHA Dec
Sun 358° 07'3 S 00° 07'2 043° 07'8 S 00° 04'2
Moon 288° 33'7 N 21° 07'5 332° 02'0 N 21° 28'3

From these Geographical Positions and the observed Altitudes (at 12:15:00 UTC and 15:15:00 UTC) the following positions are obtained:

```
solar position      N 48° 11'8   E 015° 16'9
lunar position      N 48° 10'7   E 015° 11'0
```

The Longitude difference is -5.9 minutes of arc yielding a chronometer error of about -12min. The chronometer correction will be set to 12min. In this way the chronometer time is still 3min away from UTC time, demonstrating the limited accuracy of this method. However in the middle of the ocean without time reference signals, there aren't that many alternatives!

The corrected solar position (for a correction of 12 minutes) yield:

```
corrected solar position     N 48° 11'9   E 012° 16'9
```

This position is about 30 nautical miles away from the correct position. The "solar position" is used to correct for chronometer errors, because the Latitude of the "solar position" is more accurate than the Latitude of the "lunar position".