



PRIMER FOR OXYGEN PLANNING

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Any discussion about oxygen planning should start with a familiarization of the Equal Time Point (ETP) computation. The ETP is defined as the point, where, in an emergency or contingency an aircraft is equal in time, to return to the departure airport or continue the flight to the destination airport. An ETP should be computed between "suitable" landing airports for the aircraft flown, whether over water or over large uninhabited areas. Remember, for a New York to London flight, the ETP is computed for the "coast out" airport, ie: Gander, to the "coast in" airport ie: Shannon and NOT an ETP from JFK to EGLL.

The high altitude ETP is very simple to compute using the formula; distance between suitable landing airports (D) times ground speed return (GSR) divided by the ground speed continue (GSC) plus the ground speed return (GSR). The formula looks like this:

$$ETP = D \times GSR \text{ divided by } GSC + GSR$$

You can prove the accuracy of your computation by taking the distance flown to the ETP and compute an ETA using the GSR. This would be your ETA, if your decision was to return to the "coast out" airport. However, if your decision was to continue to the "coast in" airport, you would compute your ETA using the distance remaining and GSC. Both ETA computations should be equal, proving that your ETP calculation was correct, if not correct, you must recalculate until the time enroute to the "coast out" airport and the "coast in" airport are equal.

All of the commercial flight planning agencies will compute the ETP for you and will include the ETP as an entry on your computer flight plan. Take a few minutes and check to see if the ETP furnished is correct and that the two suitable airports used are to your liking.

This cruise altitude ETP will only be used in a medical emergency or an urgent requirement at altitude, to get the airplane back on the ground. This satisfies the requirement for an ETP but has limited application, as you can see. We respectfully suggest that you may want to consider a minimum of two additional ETP's, one for a single engine condition and the other for oxygen planning purposes.

To enable you to easily see the relationship of ETP's to the wind conditions, the following examples are shown:

Distance between suitable airports:	1725 nm
True Air Speed: At FL 410 460kts	High altitude enroute



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At FL 230 300kts Single engine
 At FL 100 225kts Decompression
 (oxygen emergency)

For this example let's use zero wind conditions. Using our formula: $D \times GSR$ divided by $GSR + GSC =$ Distance to ETP: compute the equal time distance.

FL 410 $1725 \times 460 = 793,500$ divided by $920 = 862.5$ nm to ETP

Now that wasn't so hard, was it? Let's substitute our single engine TAS of 300 knots and see if our equal time distance remains the same; sure enough, the distance is still 862.5 nautical miles! Do the same for the 10,000 foot unpressurized flight level and it still remain at 862.5 nautical miles. In a no-wind condition the ETP distance will always be at the middle of the over water distance, the only thing that changes is the time to return to the "coast out" airport, or continue to the "coast in" airport. The ETE's we computed to fly to the equal time point were: at FL 410 and 460 knots the ETE to our ETP was 1 hour and 54 minutes, at FL 230 and 300 knots the time was 2 hours and 54 minutes and at FL 100 and 225 knots the time was 3 hours and 49 minutes.

Example:	ETP distance 862.5 nm	ETE at FL 410	1:54	
		ETE at FL230	2:54	
		ETE at FL100	3:49	

If we were lucky enough to have "still air" conditions at the different flight levels our decision would be simple. All we would have to consider is the high altitude ETP (1:54). If any contingency arose before reaching the ETP we would return to the "coast out" airports at the appropriate ground speed for the contingency encountered. If the problem arose after the ETP we would then continue to the "coast in" airport using the appropriate ground speed for the contingency encountered.

However, we all know that there is always a wind component to be considered. So let's add a wind component and see the effect on our ETP distance and time. For the purpose of this example we will use the same component for each direction of flight (+ in one direction - in the other). Note: those of you that are familiar with the Boeing world wide wind document will recognize that the return component is not always exactly the same as the component figured for your flight direction. We will arbitrarily use a 50 knot component at FL 410, a 35 knot component at FL 230 and a 20 knot component at FL 100. Follow us through this exercise.

FL	TAS	GSC	GSR	Distance	ETP Distance	Time to the ETP	Continue Distance	ETE
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410	460	510	410	1725nm	769nm	1:30	956 nm	1:53
230	300	335	265	1725nm	762nm	2:18	963 nm	2:52
100	225	245	205	1725nm	786nm	3:12	939 nm	3:50

Now let us prove that our ETP computations are correct:

At the FL 410 ETP we have 769nm to return at 410kts or 956nm to continue at 510kts. Our ETE to either continue or return is 1:53. At the single engine ETP at FL 230 it will take us 2:52 to either continue or return. At the oxygen ETP at FL 100 it will take us 3:50 to continue or return.

In this example our decision is simple. At normal cruise speed, both our normal cruise and our single engine ETP distances are, for all practical purposes, identical and our FL100 unpressurized flight is only seventeen miles and two minutes later. The big question we must ask is; do we have enough fuel to reach a suitable airport? In the single engine case you must make a determination for your airplane. In our example above, we must have enough endurance for 2:52 of flight plus the necessary reserves. However, the last ETP, the low altitude requires careful consideration. Note: One international air carrier uses the FL100 ETP as their only consideration. They consider a decompression at the ETP, compute the enroute time to either, continue or return, determine the fuel required and upload enough fuel to reach their destination with adequate reserves at FL100. Corporate aircraft may not have the ability to upload enough fuel to protect against this worst case scenario. Consequently, they must have the ability to climb to a higher altitude to conserve their fuel supply.

Depending on the type aircraft you fly, you must calculate a one engine or two engine inoperative ETP. At this engine inoperative ETP you will need to determine the altitude at which you can continue flight. Upon reaching this altitude and commencing engine inoperative cruise, you must figure your enroute time at the revised ground speed to determine your new ETA and fuel requirements to reach the nearest suitable airport. Experience has shown that this ETP is more valuable and useful than the high altitude ETP.

In the case of the aircraft decompression or oxygen ETP, we have to consider the altitude where we will have adequate fuel, with reserves and an adequate supply of oxygen to safely complete our flight. The oxygen ETP considers a decompression at the ETP and an emergency descent to FL100. At FL100 an evaluation of the passengers well being is conducted. Next, a determination of fuel aboard is made. Then, the distance to continue or return, the estimated time enroute, and fuel requirements must be determined. If, after making these computations you have enough fuel to reach your airport, your emergency is over and you will proceed at FL100. However, if you do not have the fuel to reach your destination (the proverbial



"wet" footprint) you must climb your aircraft to an altitude where the specific range is increased sufficiently to provide the necessary fuel with adequate reserves. If you must climb the aircraft, you now have to determine the oxygen requirements and duration at that altitude. To make this determination requires a little research into the installed oxygen system. The oxygen flow rate versus altitude, and the volume of oxygen available. ie: bottle size, in cubic feet, the bottle pressure corrected for temperature and converted to liters of oxygen available for consumption. If you have not considered oxygen planning as part of your flight, you now, in the middle of this emergency, have to play catch up. The oxygen evaluation requires some in depth research. We respectfully submit that it can and should be accomplished without the stress of an emergency problem. There is no time like the present time to begin your evaluation process.

A story about an air carrier aircraft that experienced a decompression was recently related to us. The crew upon recognition of the decompression, started their emergency descent, leveled the aircraft at 14,000 feet and much to their chagrin, determined that they did not have enough fuel to reach their destination. Their course of action was to climb the aircraft until the fuel specifics were adequate to assure a safe landing at destination. Upon landing, some passengers required medical attention, several had serious problems due to hypoxia. We are trying to verify this occurrence using NTSB reports but as of this writing have been unable.

We first became aware of the oxygen ETP requirement about ten years ago at a NECAA international seminar. Don McKeown, then with Flight Safety International, pointed out the value of computing an oxygen ETP. This was a new idea then. The next day back at National Distillers we decided to learn more about our aircraft's oxygen system. We were operating a GII and a GIII at the time. Our learning process took us almost three years before we had a system we felt comfortable with. We had to develop aircraft fuel and range charts and the oxygen duration charts that would give us the planning document that would be helpful in the decompression scenario.

One of our first discoveries was that the GII had more installed oxygen aboard than the GIII. Why the difference? We found that the oxygen system design was predicated on a San Francisco to Honolulu flight with a 90 knot head wind component with full fuel aboard. This was considered the longest over water flight requirement in the world. The 90 knot component was considered the maximum that might be encountered. The oxygen system was designed using this criteria. At the ETP (worst case) the aircraft had to have enough fuel and oxygen to either return to departure point or continue to destination. With more fuel aboard, a lower flight altitude could be tolerated and therefore, less oxygen was required. The GII had 23,000 pounds of fuel and 406 cubic feet of oxygen, the GIII had 28,000 pounds of fuel and 278 cubic feet of oxygen.



We then needed additional information to compute the oxygen used in the descent profile, the flow rate at the cardinal altitudes of 15,000, 20,000, 25,000 feet. Note: The continuous flow system used for the passenger system is only certified to 25,000 feet. John Dow, of Dow Aerospace was contacted to fill in some of the oxygen system blanks we still had. John had designed the GIII oxygen system when he was with the Page Avjet engineering department, San Antonio, TX. Pete Hellsten, the Gulfstream Aerospace preliminary design guru and aerodynamicist extraordinaire was asked to help us in designing a range chart for the GIII. Don McKeown of Flight Safety, provided us with the overwater planning essentials. With this group of interested individuals providing the expertise and we (Stabile and Mack) providing the "donkey" power, we were off and running at last!

We then began the long, arduous task of planning for the worst case scenario, a flight from KSFO to PHNL against a 90 knot headwind. At the ETP we had an engine failure followed by a decompression. Could we make it to either our "coast out" airport or our "coast in" airport? We found that, using this scenario we would have had a "wet" footprint. We would be short of KSFO by 75 miles. The immediate problem was to find the altitude that we would need to climb to, in order to gain the 75 miles plus fuel reserves necessary. The next problem was to inventory the oxygen system, calculate the flow rates at the new cruise altitude, multiply the rate by the number of passengers and decide if the supply was adequate. After this exercise we realized that the appropriate time to do our planning was here, on the ground and not over the Pacific in an unpressurized Gulfstream.

That was the "worst case" scenario for the GII. Don McKeown always played the devils advocate. I remember saying to Don that it was such a remote case that it would never happen to me in my lifetime. He presented me with another scenario; how about a GIII departing Denver enroute to Honolulu direct. As you pass overhead SFO you are now a GII in terms of range. However, you are in worse shape because you do not have the same oxygen duration as a GII. Remember, the GIII had more fuel and less oxygen than the GII, and now you have consumed some of your fuel on the flight from Denver. This, of course, is an avoidable situation, Don's advice: "never fly over a gas station". If you do, you should have a plan and knowledge of your range and your oxygen duration. We always felt it a novel idea to have the ability to turn oxygen into range by having the capability of climbing to a higher altitude thus extending your range.

We concluded, after these "what if" exercises that we required a condensation of all this information into a quick, accurate and easily useable format, so that in the unlikely event of a catastrophic failure we would have the necessary planning documents readily available.

Out of curiosity, Jim Stabile decided to verify just how "unlikely" a catastrophic failure would be. He began to research the accidents reported that involved a corporate aircraft decompression. The information was extremely difficult to obtain and verify.



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Bob Breiling of Robert E. Breiling Associates of Boca Raton, Florida, was contacted. Breiling Associates specialize in reporting and documenting corporate aircraft accident statistics. According to N.T.S.B. reports there have been 17 decompression accidents involving U.S. registered corporate aircraft since January of 1966. Of these accidents, four were window failures, one a window separation and one a door separation. More than 60% were caused by an uncontained engine failure, with engine debris penetrating the pressure vessel, culminating in a decompression.

These numbers speak for themselves and it may be prudent to change our "what if" to "when it happens". Another point to be considered, before we move on, these statistics are accidents, not incidents. There are many incidents that have occurred and not resulted in an accident. Therefore these "incidents" may not be reported. The statistics do not include air carrier aircraft. We all remember the United B-747 that had a cargo door depart during climb out of Honolulu, the Hawaiian Air 737 that became a "convertible" and the U.K. Midlands aircraft that lost a windscreen, which the first officer landed safely with the captain hanging out the window. Some of these accidents can be attributed to "aging" aircraft. The corporate fleet may be entering this era. Pilots, please note, this information is presented for your perusal and edification and hopefully the start of your planning. Let's get on with our planning documents.

We first developed our fuel range charts for the cardinal altitudes, 10, 15, 20 and 25,000 feet. (Twenty five thousand was the maximum certified altitude for a continuous flow oxygen system). We created these charts with the guidance of Pete Hellsten of Gulfstream Aerospace. These charts allowed us to use fuel, time or distance with a wind component correction to find our range with suitable reserve fuel.

This graph, provided quick, easy answers and gave us the ability to "cross check" the performance of the aircraft in any regime of flight, any time, at the cruise altitude selected. Therefore, we named this chart our "how goes it" chart. This graph was prepared specifically for our GIII serial number 301 and provided a reserve of 2,000 pounds of fuel overhead the destination airport. All of our "how goes it" charts have some amount of reserve incorporated into the chart.

With the fuel and performance analysis completed we moved on to our oxygen planning document. This document required more in depth research, for a reasonably simple system, than we had anticipated. The research took many long hours to accumulate the data and shape it into a usable format. The oxygen matrix was not as complex in theory as the fuel planning. It was basically addition and subtraction but a very tedious task. We won't elaborate at length but here are a few examples of the information necessary to develop a usable matrix. First we had to learn the oxygen system capacity. Then we had to develop a chart to compensate for temperature and pressure in those bottles to find the actual cubic feet of oxygen aboard. The oxygen mask and regulator manufacturers were asked to supply the flow rates for the mask/regulator combination



for our cardinal altitudes. Gulfstream provided the descent rates for the aircraft in an emergency descent profile. We then took our high altitude cruise level, found the time to descend to 10,000 feet, averaged the flow rate for the number of passengers using oxygen, added the crew masks using 100% oxygen and determined the amount of oxygen expended in the descent profile. We used this calculation in our flight planning and evaluation. Additional calculations that were time consuming, was converting the bottle pressure and temperature into cubic feet available and then converting the cubic feet to liters of oxygen available. All of the flow rates for the oxygen masks are in liters per minute. Until we did this analysis we never had a clue on how to make the conversion. Do you?

The oxygen idea was easy.....time versus oxygen rate! However, getting there was another story. If you look at our oxygen matrix it is very simple to read. Merely know how many passengers are on board read upward to how long you will be at that altitude and then read across to find the oxygen required in liters. A crew of three was included, we separated the oxygen used in an emergency because that will not always be the case. You may have a situation where a slow descent will be necessary and not require the high flow rates associated with an emergency descent.

HOW TO USE THE CHARTS

Suppose we are making a Trans-Atlantic crossing and as we reach our ETP all hell breaks loose! Number two engine fails due to a rotor burst that penetrates our pressure vessel. We are suddenly on one engine in an unpressurized aircraft! A rapid descent, on oxygen, is initiated, the aircraft is leveled at 10,000 feet, a cabin check is made and all is well. We now try to collect ourselves and decide our course of action. We check the flight plan wind forecast at 10,000, calculate the ground speed and compute the time to our nearest suitable airport. Pull out the "how goes it" LRC chart for 10,000 feet. Enter the chart by either time, fuel or distance to see if there is enough fuel to continue the flight at 10,000 feet, keep in mind that on this chart we have a 2,000 pound fuel reserve added to it.

If you can make destination at 10,000 feet your emergency is over! If you cannot make it at 10,000 feet, you now go to the 15,000 foot chart and see if you can make it, if not continue up to the 20,000 or 25,000 foot charts to see at what altitude you can make it. Once you have established a "fuel" altitude, look down to the next page (it has the oxygen duration chart for that altitude) and see if you have enough oxygen aboard, based on the time to destination versus the number of passengers. You may find yourself in a predicament where you have enough oxygen but not enough fuel and now you must convert the oxygen duration into fuel by climbing to a higher altitude.

We know, unequivocally that faced with this problem without any prior planning you would be like a fish out of water.....but not for long! This all sounds overwhelming, but it isn't.



With the aid of our fuel/oxygen analysis, you can tackle and successfully cope with any fuel/oxygen problems that may arise.

SOME FOOD FOR THOUGHT

Several years after we had completed our project we were on our way from Manaus Brazil to TEB, when over the Caribbean, we had a door seal failure and the aircraft slowly decompressed. I was assigned the task of wetting towels and stuffing them around the door, attempting to create a better seal, in hopes of lowering the cabin altitude. When this was done I returned to my position to find that Bill Mack had already assessed our situation with the aid of our charts. Luckily our emergency was over! We had the tools to make the determination and we used them.

We spoke with a GIII pilot that had recently returned from a trip to China. He related a problem he faced on his return flight. When doing his pre-flight inspection the crew discovered that their oxygen system had leaked down to about half pressure. They immediately tried to have the system serviced but discovered that the Chinese have a regulation or policy that prohibits them from servicing installed bottles. They were now faced with a departure delay or proceed without knowing their oxygen duration. With an oxygen planning document available they would have known their oxygen duration instantly.

In some of the European countries their oxygen servicing fittings are not compatible with our standard fittings. If your system has less than full pressure, and you have not documented your system, you will not know what your oxygen capacity or duration is and may find yourself between the proverbial rock and a hard place when making your decision.

The "how goes it" charts and the oxygen planning documents have a "Universal" application and the prudent pilot should have these tools available.

These documents allow the pilot to make solid decisions based on knowledge rather than guesswork.

This documentation provided to the client is "tailored" for the individual aircraft, in accordance with the Supplemental Type Certificate for that aircraft. The documentation will remain as an aircraft document, unless a change in aircraft performance or a revision to the oxygen system is made.

In addition, we have developed a software program that is also available. This electronic program is developed from the information contained in the Oxygen Planning Product (OPP). It will operate on any windows based computer that has excel 7.0 or higher. Included in this



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program are ETP calculations and flight planning capabilities that are needed to determine oxygen requirements for specific flights. This information will calculate, BEFORE you leave the hangar how many liters of oxygen and how much fuel and what altitude you will need to climb to in the unlikely event of a decompression at the ETP. It can also be used dynamically during an actual emergency.

This information has been presented at several international seminars and always stimulates the group into starting the preparation of their own plan. The main thrust of our presentation, has always been safety first. These are things you should know before you go. We also know how long it takes to put together a comprehensive plan. It takes a lot of perseverance to complete this type of documentation. Aeronautical Data Systems now offers this service so that the people that operate on that edge of the envelope will have the required information available to them.

Good Flying!

Jim and Bill

Jim Stabile and Bill Mack

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