ADAPTATION OF WATT'S INDICATOR MECHANISM IN ALTITUDE MEASUREMENT

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ABSTRACT

The most important systems being used for the effective and safe operation of an airplane is the Altitude Measurement Systems, a duty carried out by means of an Altimeter. The Altimeter output is affected by the input that is given to it. The input that is used by the Altimeter to show the desired altitude is nothing but the barometric pressure at the height at which the aircraft is travelling in.

The barometric pressure is converted to the appropriate altitude by means of either Pitot Tubes or Sensors. The Pitot-tube is being used widely in all commercial airliners. The Pitot-Static systems are extremely susceptible to blockage by foreign bodies in case the aircraft sits on the tarmac for long time.

To avoid contamination of the liquid which senses the change in pressure, the pitot-tubes are covered and if this cover is not removed, the pitot-tube gets blocked. Sensors are extremely susceptible to be burdened by ice, and in cases where the heating is not available in the place where the sensors are kept, erratic altitudes may result.

*It is therefore proposed, theoretically, to make efficient use of a four bar chain mechanism, called the **Watt's** Indicator Mechanism, in order to eradicate the effects of blockage by foreign matter and burdening by ice and thereby promoting the effective measurement of Altitude in Airplanes. This mechanism would be able to provide means of measuring altitude if calibrated appropriately.*

KEYWORDS

Pitot-Static Systems, Sensor, Watt's Indicator Mechanism, Barometric Pressure, Failure Mode Effect Analysis (FMEA)

1. INTRODUCTION

This document emphasizes on the need for an effective and safe method of measuring altitude in addition to the present systems of Altitude Measurement like the Pitot – Static Systems and the Sensor Systems. Due to inherent problems and contradictions in each system and imminent drawbacks in the same, the four bar chain mechanism, The Watt's Indicator Mechanism has been used to study its effectiveness in the Measurement of Altitude in Aircrafts.

The paper focuses on the need for the development of alternative systems of Altitude Measurement, thereby developing newer and safer instruments that would feed the altimeters of future aircrafts. The Watt's Indicator mechanism, in its most primitive state, is an analog device that responds to change in atmospheric barometric pressure and the movement of a link indicates the correct altitude of the aircraft.

2. PROBLEMS IN THE PITOT – STATIC SYSTEM

The Pitot – Static Systems in an aircraft are mounted towards the side of the aircraft or are seen as small pipes that are projected towards the front of the aircraft. During the cleaning of the exterior of the aircraft, it is often a usual practice to cover the pitot tubes by a tape in order to avoid contamination of the liquid inside the tube which senses the changes in pressure. But if the tapes are not removed after cleaning, then the pitot tubes will get blocked resulting in erratic altitude readings.

Also, if the flights are parked on the ground for long times, and as per regulations if the pitot tubes are not covered properly, it may result in some contaminant settling in the pitot tubes and once the flight is operated, it may lead to complete pitot – static failure and the flight will be in jeopardy.

If the two reading of the vertical speed, one of the captain and the other of the first officer, do not agree with each other, the auto – pilot may simply disengage. Also, if both the pilots' readings agree but with the wrong value, it is a great cause of concern.

EXAMPLES:

1. Aero Peru 603, lifted off at Lima, Peru and crashed soon after into the Pacific ocean due to the Pitot – Tubes being covered with tape during the cleaning of the aircraft and was not removed prior to flight.
2. Birgenair 301, took off from the Dominican Republic, and also crashed very soon due to a small insect called the Mud Dobberwasp building its nest in the secluded area of the Pitot – tube. This was the result of the Pitot tube not being covered when the flight was parked on the ground.
3. Air France 447, the most recent one in the line of events, crashed into the Atlantic Ocean after lifting off from Rio – de – Janeiro due to suspected Pitot – Tube problems. It is to be noticed that the aircraft flew into very bad weather over the Atlantic.

3. PROBLEMS IN THE SENSORS

The same problems with the Pitot – Tube can be correlated with the sensors too. The aircraft's sensors may get burdened by ice when the flight flies through heavy thunderstorms and convective activity around an area. This may lead to erratic reading and lack of agreement between the captain's and the first officer's air speed reading. This may lead to the auto – pilot summarily disengaging. The same problem can in fact cause disagreement of Altitude Readings also. An easy way to comply with the conference paper formatting requirements is to use this document as a template and simply type your text into it.

EXAMPLES:

1. Air France 447, had its Speed Sensors Malfunctioning and even gave an automatic message to the ground station indicating complete Electrical System Failure, 4 hours into the flight.

4. THE WATT'S INDICATOR MECHANISM:

The Watt's Indicator Mechanism is a simple mechanism consisting of a piston used to sense the external pressure. The piston is connected to a link and the link is, in turn, connected to a V- Shaped chain. One end of the V- Shaped Chain is connected to a point which is pivoted and fixed. The other end of the V- Shaped Chain is free to move over a vertical scale.

The point, worth noting, in the Watt's Indicator Mechanism is that the free link that moves over the scale generates a straight line. This is the primary reason, why the Watt's Indicator Mechanism is also called as the Straight Line Mechanism.

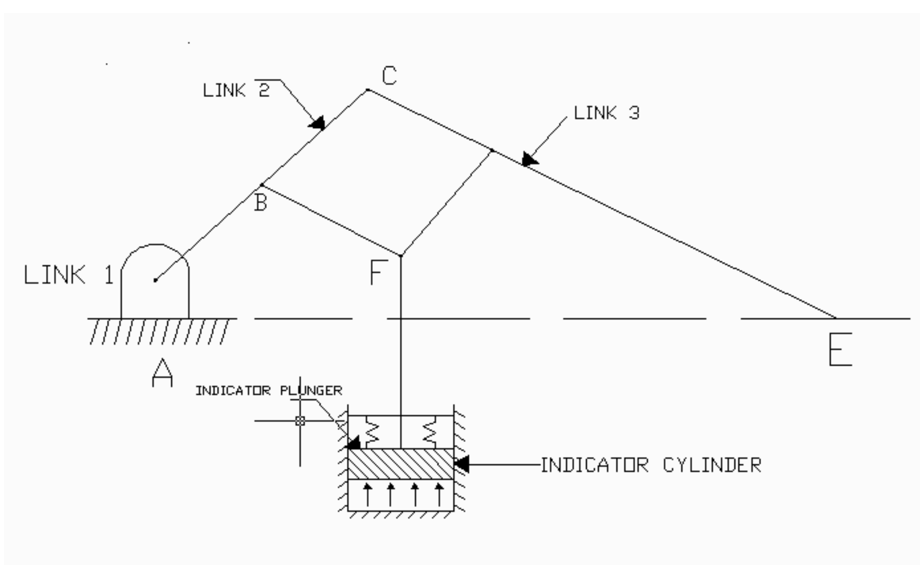

Figure 1. Schematic Diagram of the Watt's Indicator Mechanism

Figure 1 shows a schematic diagram of the Watt's Indicator Mechanism. Here, in the bottom portion, there exists an indicator cylinder, which is acted upon by external pressure as depicted by arrows. The indicator cylinder is also supported by two properly designed springs, whose functions are explained later.

The indicator cylinder is connected to the V- Shaped link at Point F. The point F is connected to the Links 2 and 3 at points B and D respectively. It should be noted that point F is the point that moves with corresponding reciprocation of the Indicator Mechanism.

Link 1 is pivoted at Point A, so that the movement of Point F will induce only an oscillatory motion in the Link 1. Link 2 terminates at Point E, which is free to move over the calibrated scale which will bear the altitude markings.

5. APPLICATION OF WATT'S INDICATOR MECHANISM TO ALTITUDE MEASUREMENT:

Table 1: Air Pressures at Different Altitudes

S. No.	Altitude (In ft)	Air Pressure (In bar)
1	Sea Level	1.013
2	5000	0.815
3	10000	0.655
4	15000	0.527
5	20000	0.424
6	25000	0.341
7	30000	0.274
8	35000	0.220
9	40000	0.177
10	45000	0.142

Table 1 gives the Air Pressure (in bar), at altitude in increments of 5000ft up to a hypothetical altitude of 45000feet. Here, from this table, it can be seen that, the atmosphere starts to thin, as we climb further upward. The maximum Air pressure of 1.01325 bar is present at Sea Level. So, the mechanism, which has to be designed for the maximum, has to be designed in such a way that it undergoes full compression at Sea Level.

Let us assume that, for a properly designed indicator cylinder diameter, if we give a pressure of 1.01325 bar, the freely moving link, which terminates at Point E, moves over the calibrated scale for a distance of 10cm, then we can convert the distance measured into a corresponding altitude, and mark the distance of 10cm as Sea Level or 0feet.

In this manner, we can, supply pressures in the increasing order, and correspondingly note the distances moved by the needle. Surely, the distance moved by the needle, when we give the pressure at Sea Level will be much higher than the distance moved when the pressure at an Altitude of 40000feet is given. So, accordingly, the distances can be converted into corresponding altitudes.

The springs, deserve a special mention here, for the fact that, if the plane climbs, say from 20000feet to 25000feet, then the corresponding air pressure decreases. So, there is no mechanism by which the indicator cylinder responds to the change in air pressure. The compressed springs, push the indicator cylinder down, till the point where the force exerted by the spring is same as the force exerted on the cylinder by the air pressure. Consequently, the needle comes down, thereby indicating the correct altitude.

6. DESIGN FMEA PROCEDURE FOR THE MECHANISM:

Table 2 :Design FMEA Procedure

S. NO	FAILURE MODE	FAILURE EFFECTS (KPOV)	CAUSES FOR FAILURE (KPIV)	SEV	OCC	DET	RPN
1	Failure of Springs	Erratic Altitude	Mechanical Breakdown and Wear	9	6	5	270
2	Failure of Links	Erratic Altitude	Mechanical Breakdown of Bolts	9	4	2	72
3	Ripping of Indicator Cylinder	No Measurement of Altitude	Flight in uncontrollable dive due to other problems	9	1	5	45

Table 2 depicts a Design Failure Mode Effect Analysis (FMEA) Study on the Watt's Indicator Mechanism reveals a startling prospect. The Risk Priority Number (RPN) is more than the standard of 125 for the Failure of Springs. Nevertheless, Preventive Action has been suggested for the first two failure modes.

6.1. Preventive Action

1. The springs are subjected to fatigue loading. The springs should be made of a material that resists wear and has a very high endurance limit. Also, it is recommended that the springs be inspected at the end of a certain number of flights, which can be decided once the material has been finalized.
2. The bolts that are used to keep the links in place are subjected to severe loading as the plane climbs or descends, because the altitude is changing per second in these operations. So, it is recommended that the entire assemblies of links are checked each day by the process of calibration i.e., giving a particular pressure and matching the altitude given with the correct one. Also, during the end of the week, the entire assembly is taken out and the bolts are replaced if necessary.

7. ADVANTAGES OF THE MECHANISM:

The measurement of altitude of an aircraft by the use of a Watt's Indicator Mechanism has many advantages, some of which are listed below.
1. Less dependence on the use of the Pitot – Static System, the susceptibilities of which have been said earlier.
2. Altitude Measurement Sensors have been replaced by the system, which eradicates the problem of burdening of ice.
3. The problem of fluid contamination in the Pitot – Static System is eradicated as there is no use of fluids in the Watt's Indicator Mechanism.
4. There are no small gaps or crevices in the Mechanism, which makes it impossible for foreign matter to settle on the system.

8. DISADVANTAGES OF THE MECHANISM:

Like everything and everyone, the Watt's Indicator Mechanism has its own kind of disadvantages which have been mentioned below.
1. The process is completely composed of mechanical components which are susceptible to sudden failure. Constant and thorough inspection is required.

2. In this mechanism, the needle moves backwards as the altitude increases. Pilots should have extensive training on this mechanism, as the needle in any measurement system, will move forward with the increase in the physical quantity. Improper and Insufficient training in this system will be catastrophic.

9. POSSIBLE INNOVATION:

The displacement of the pointer could be sent to a microprocessor which has been fed with the program to convert air pressure into the corresponding altitude readings. This altitude reading could be given to the pilots in a digital format eradicating the calibrated scale.

10. CONCLUSION:

This technical paper strives to change the way we travel. The small but critical changes in the way Altitude Measurement is done on the Aircrafts could well be the difference between a safe flight and a jeopardized one. Or at least, let us hope so.

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