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PROBLEMS RELATING TO DRYNESS IN THE UPPER AIR LANES DURING JET FLIGHTS /13*

J.Fritze

ABSTRACT. Problems in high-altitude jet flying are discussed, from the physiological and psychological viewpoint. Emphasis of the investigation is on possible permanent or transient damage to the organism by low relative humidity of cabin air. Remedial measures are mentioned, including individual humidifiers, wearing of artificial noses familiar from post-tracheotomy therapy, and careful supervision of otologic conditions of crew members.

In 1960, the Scandinavian Airlines System (SAS) began using jet-powered aircraft. The advantages derived from using such aircraft instead of the propeller type are, inter alia, greater reliability, less expensive fuel, less noise on board, in addition to less time spent in flight due to the higher speed.

Flying over great distances takes place at high altitudes where the weather usually is good, where the flight generally proceeds with strong tail winds and in thin air, which offers little resistance to the forward motion of the plane and thus ensures economic use of materiel.

Over the years that jet aircraft has been in use, the author of this paper has conducted a great number of the required semi-annual health examinations of the crews flying these planes.

Before many months had passed, it became evident that certain complaints by the personnel constantly recurred. These were complaints they had never made when flying on propeller aircraft.

Among the complaints, we can mention the so-called jet fatigue. Whether this is an actual phenomenon, one cannot say. It was first put forward by the French Association of Airline Pilots in 1960, following an investigation made by a physician hired by the Association. Upon the conclusion of transatlantic jet flights, the crew complained of feeling much more tired than after trips over the same distance with propeller craft taking a longer time. There was greater need for sleep, greater irritability, and getting back to normal took as much as several days. Perhaps it is the east-west flights with the great time differentials that bring fatigue in their wake? It is easy to imagine that it is difficult to get some rest in a hotel room in noisy surroundings, having to sleep during the day after a night flight. Also, the reason for the greater fatigue may be due to the shorter flying time. The manipulations necessary /14 during a flight have to be attended to within a shorter period of time. In pro-

* Numbers in the margin indicate pagination in the foreign text.

peller aircraft, it was possible to get some rest between chores, while in jet aircraft it is necessary to do the "checking" almost without letup. The work tempo has been stepped up greatly.

In a plane of the DC-8 type, it is possible that the vibration from turbines and compressors may affect the general state of health. In this respect, one could mention the well-known phenomenon that a stay on board a motor torpedo boat produces a feeling of discomfort, one reason being the vibrations.

Fatigue, of course, is a sensation difficult to measure; we are a little better off concerning the other frequent complaint, namely, the dry air on board the aircraft, generally occurring during flights over great distances and at great heights.

If, in making a physical examination, the person is asked what is most annoying in flight, it will be found that, on DC-8 aircraft, there are frequent complaints of dryness of the mucous membranes of nose and mouth, dry lips, dry skin, scales forming on the scalp, and smarting eyes. The symptoms confined to nose and throat are exhibited by the majority, estimated as between 80 - 90%.

When Captain Uffe Darket of SAS spoke at a meeting of our club in the autumn of 1964 and listed the various problems facing the pilots, he also presented a diagram indicating how many pilots of jet aircraft were bothered by dry air. A total of 180 jet pilots, all members of the Danish Airline Pilots Association, had replied to the submitted questionnaire, and of these 1/3 had answered in the affirmative. The plane types DC-8, Coronado, and Caravelle had been lumped into one group. However, only very few complained about this trouble with respect to the latter two types, the reason being that they are used on routes with flying times seldom exceeding 2 or 3 hours per leg. In these cases, the time is too short for such symptoms to appear.

It should be mentioned that pilots of the Air Force do not voice complaints of this kind, due to the little time spent in the air between airfields, usually not more than one hour. The problem mainly concerns the crew members on DC-8, which chiefly are used on the route between the US and Scandinavia, crossing the Atlantic to New York, in addition to polar flights via Sondre Stromfjord and Anchorage, to Tokyo, Los Angeles, and Chicago.

As regards the altitude of flying on these routes, the initial height is /15
about 28,000 feet. This altitude is maintained for an hour or two, after which the plane, as its weight decreases with depletion of the fuel, gradually ascends to a height somewhere between 33,000 and 38,000 feet.

The pressure in the cabin is maintained by compressors, remaining at approximately sea-level values up to 23,000 feet altitude. Above this level, the pressure is lowered somewhat; at 38,000 feet, for instance, the pressure will be equal to that at 8000 feet.

The temperature at these high levels varies between -55°C and -65°C.

The R.A.F. meteorological service, in balloon ascents, has found the relative humidity at a height of 40,000 feet to be about 1%, at -60°C. This cold

and dry air is taken into the aircraft, is heated, and sent via compressors to the cockpit and the passenger cabin.

The air in the cockpit is changed every $1\frac{1}{2}$ minute and in the cabin, every $3\frac{1}{8}$ minute. The air taken in, with a humidity of 1%, is heated to a temperature about 80°C higher than its original level. The relative humidity in the final air mixture thus will be a negligible quantity.

The maximum capacity of the cabin is 144 passengers; this number of people will contribute to increasing the moisture content of the air, partly through perspiration and partly through the moisture contained in the expired air. In addition, the food and drinks served will give off minor quantities of water vapor.

The crew members in the cockpit, however, does not derive any benefit from the added water vapor, since - as indicated above - two separate circulation systems exist, coming into contact only when the doors are opened for some one to pass from one area to the other.

The very rapid air circulation quickly eliminates any water vapor created, actually amounting to no more than 100 liters per flight.

During the winter of 1963, various measurements were made of the relative humidity on board a DC-8, upon the initiative of Captain Jessen of SAS. The captain used a hair hygrometer, of the Lambrecht type, supposedly a very sensitive instrument. The measurements were made by the system operator, on his panel in the middle of the cockpit. This was supposed to be a neutral spot, where the instrument would not be affected by air currents, by the heat from the panels, or by other disturbing factors.

The temperature in the cockpit is kept between 20° - 22°C.

When flying in daylight, both pilot seats are in addition exposed to the rays of the sun, since there are window panes above and at the side of these places. This "dry roasting" is said to be very unpleasant.

In a resumé of the material collected, Captain Jessen contended that the /16
measurements clearly indicate that after about one hour's flight the relative humidity in the cockpit is 5 - 10%. Some measurements were made in the passenger cabin, showing slightly higher percentages, namely 10 - 20%.

The complaints include a feeling of dryness in the nose, in the throat and in the connecting areas, in addition to an increased itching in the nose and burning in the throat. There is also an increased tendency to incrustation in the vestibulum nasi, followed by cleansing processes. Some crew members complained that their voice becomes hoarse and rasping, and even fails at times; there is a tendency to dry cough and clearing of throat is often required.

It is claimed that colds are more frequent and last longer than in earlier flights in other types of plane.

A head cold during the first few days after returning home is a frequent

complaint but is never reflected in the sickness reports, since there almost always are 5 or 6 days before the next trip. The person will just stay indoors until his cold has subsided.

The feeling of dryness disappears rather quickly in most people as soon as the flight is over; some take a shower and find it helpful while others will sniff water or salt water through the nose.

In one particular locality, namely in Anchorage, it seems difficult to return to normal nasal condition, probably caused by the dry air in Alaska.

If we look at the various climatic conditions throughout the globe, we find that there are certain regions with very low relative humidity such as the polar regions where the air is cold and dry, in addition to desert areas such as Arizona where the air is warm and dry. In both areas there are permanent inhabitants, showing that it is possible to live in a medium of low relative humidity. We have learned that North American Eskimos when brought south to be hospitalized, do not feel well in breathing the more humid air in these localities. Examinations of Eskimos showed no differences in regard to nose and throat that may be due to their living in areas with low relative humidity. Nor can one point to increased frequency of diseases of the respiratory tract; on the contrary, they are rare. Anatomically speaking, there is nothing to indicate that the respiratory tracts of Eskimos are superior to those of other races.

During Mount Everest expeditions, reaching altitudes of 22,000 feet, the /17
members have been bothered by troublesome mucous membranes, in the form of dryness, incrustation, and ulcerations.

These conditions are comparable with the DC-8 climate which is influenced by low temperatures and the rarefied air.

That life proceeds normally in the above localities of low relative humidity, is due to the fact that the inhabitants have lived there a long time, so that the possibility exists for acclimatization.

During the approximately 40 flying hours per month put in by the DC-8 crews, divided into perhaps five trips lasting about eight hours each, with a stay of 4 - 5 days in climates of normal humidity, one cannot expect acclimatization to take place. It is possible that the human organism would adjust to the conditions and that the symptoms would decrease, if one settled permanently in the kind of climate represented by the air in a DC-8 cabin. Observations made on persons who had undergone tracheotomy can be cited in support of that view. When a sizable part of the normal respiratory tract has been dissected in a tracheotomy, there will be increased dryness of the tracheal mucous membrane, some irritation, and incrustation to a varying degree. However, this is almost always a transitory symptom; in the course of 2 - 4 weeks the mucous membrane becomes used to the new conditions and the incrustation ceases. Among some persons, though, it may continue as long as the tracheostoma exists.

On the whole, it has been shown that tracheotomy patients are bothered with scale formation to a much greater extent in modern hospitals, such as the dis-

trict hospital in Glostrup which has an excellent air-conditioning system, than they are in the older buildings of the Blegdam Hospital and the Finsen Institute. It is rare that the air is effectively humidified in modern glass-and-concrete buildings; a relative humidity of 25 - 30% is not rare in these buildings.

In discussing these matters, let us look at the normal respiratory tract, its structure and function, its secretion of water, and dissipation of heat.

Air is inhaled through the nose; via the rhinopharynx and the pharynx it reaches the larynx and from there the trachea and bronchi, ending up in the bronchioles and alveoli. Along the way, the air is treated to form an ideal "product" of use for the alveoli.

In these, heating and moistening take place, together with a certain filtration in that dust particles and bacteria are held back, especially in the cavum nasi, where these elements are deposited on the mucous membrane above the epithelium. Through marks made in the layer of mucus it has been found that this layer is renewed 2 - 4 times per hour. The mucous layer is produced by the goblet cells and the submucous glands and, with aid of the cilia, is moved back toward the rhinopharynx where it is swallowed. /18

This purely mechanical cleansing process is possibly supplemented by a process affecting any bacteria that might have entered the area. Some researchers are of the opinion that the secreted material lysozyme contains an agent that helps dissolving bacteria. There is, however, disagreement on this point. It seems that only harmless bacteria are affected, while the harmful ones survive. At any rate, if the normal mucous layer dries excessively, it becomes easier for bacteria to attack the cells of the mucous membranes.

When the air breathed in is ready for use, i.e., has reached the alveoli, it is heated to about 37.5°C, and is also about 100% saturated with water vapor. The heat is supplied on the way by the mucous membranes. Temperature measurements made in the respiratory tract of normal people indicate that, at an ambient temperature of 17 - 21°C, the temperature of the air is increased by 12 to 15°C after it has passed through the nose; measurements show about 32° in the rhinopharynx, about 34° in the pharynx-larynx, and as much as 36° in the trachea.

The temperature at the surface of the mucous membrane in the nose fluctuates with the respiratory cycle, falling to about 30° after inspiration and rising to about 32° on expiration.

In measuring the temperature of the nasal mucous membrane, it is found to be constant near 33 - 35°C, depending on the skin temperature.

The temperatures of the respiratory tract thus show that there is a progressive increase until the air reaches the alveoli. This is of practical significance, since the dew point is not reached and the moisture cannot condense to water.

Because of the rising temperature of the inspired air, it is able to assimilate more water vapor, the farther it reaches distally. As mentioned above,

heat is dissipated by the mucous membrane of the nose which - in turn - picks up heat from blood vessels. The submucosa contains a system of arterioles, sinusoids, and arteriovenous connections that are controlled over the autonomic /19 nervous system. The sympathicus has an arteriole-contracting effect, while the parasympathicus has a dilatory effect. This system is able to make the nasal mucous membrane adjust to different tasks.

The temperature of the expired air drops gradually as it passes along; it is 37 - 36° in the trachea, 36 - 35° in the pharynx and 31 - 32° in the nares when breathing through the nose.

As mentioned previously, the ability of the inspired air to transport moisture increases with increasing temperatures. Thus, the moisture of the inspired air must be supplemented. This takes place in the nose, via some glands located anterior to the two sides of the septum. These glands have afferent ducts of about 3 - 4 cm in length and emptying in front of the septum. They secrete very fine droplets that are entrained by the inspired air.

The greater part of the water, however, comes from transudation via the intercellular spaces; water is given off by large thin-walled exepithelial vessels.

During expiration of the moisture-laden air of 37.5°C the temperature falls until the dew point is reached and water vapor condenses on the mucous membranes. It has been estimated that about 50% of the moisture content of the expired air is retained in this manner.

This demonstrates that inspiration air of low moisture content places greater demands on the organism to render this air useful.

According to Lundsgaard, evaporation from the respiratory tract, under normal conditions, is about 300 cc per 24 hours, a very small percentage compared with perspiratio insensibilis which is about 1000 cc and with urine excretion which is about 1000 - 1500 cc (with the value for the feces being 200 cc).

Normally, the production of water (or moisture) per 24 hours is 2000 to 2500 cc, including the water of oxidation of metabolism which is about 300 cc.

This raises the question of alleviating this troublesome factor for the crew members of DC-8 aircraft. It is obvious that the moisture deficit must be compensated. This is actually being done; most crew members report that they consume 1 - 1½ liters of liquid on a long flight, mostly in the form of soda water or cola. Some drink coffee or tea, but the diuretic effect of caffeine contraindicates the drinking of these liquids. Urine excretion is minimal, with the urine having a dark color and strong odor. Increasing the moisture content of the entire cabin air is impossible. When this particular type of aircraft was first introduced there was some discussion as to the advisability of installing humidifiers on board, but such an installation would weigh about four tons and would take up much space, so that it was not thought feasible. /20

On the other hand, there might be some way to provide individual humidification of the air for each passenger.

Flight regulations provide for one of the pilots to use an oxygen mask when flying at great altitudes. Such masks are unwieldy and uncomfortable, and people prefer not to use them. Possibly, less uncomfortable types could be devised, perhaps connected with some kind of humidifier. Such an installation should be possible without excessive bulk or weight.

Another possibility is the construction of an artificial nose of the type used by patients after tracheotomy. The principle consists in condensing the expired air by passing it over a system of light-metal lamellae; during inspiration, this moisture is entrained with the inspired air and can thus be re-used. Such a "nose" would no doubt save on water, and will probably not be too uncomfortable. Various types of sprays might also be useful. This should be investigated further.

Conventional medical and otologic treatment must be given when needed, the general health must be good, and any nose or throat disorder must be cleared up. Perhaps it would be useful to conduct a systematic examination of the entire DC-8 personnel; this could include a listing of their functions and complaints, determination of the total loss of moisture during a long flight, weight-taking before and after flight, measurement of urine excretion, and so on. This might yield a criterion for future selection of crews for DC-8 aircraft and similar types. Of course, some pilots have no complaints; these belong perhaps to the category of individuals able to live comfortably in dry air. Whether permanent injury may occur in the nose is impossible to say; it might well be that the mucous membrane is injured when these conditions prevail over a number of years. For example, epithelial metaplasia has been observed in the trachea of patients after laryngectomy. The mucous membranes of such patients are exposed to drier air than they can tolerate, with the relative percentage being 60 - 65.

It would be of interest to check whether similar conditions might be found in industrial enterprises. If such were the case, data could be obtained on prophylaxis and therapy.

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