PETERSON FIELD GUIDES

Atmosphere

CLOUDS • RAIN • SNOW • STORMS

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In this era of high-flying aircraft, condensation trails —contrails— are a commonly observed feature of the sky. **Sometimes they are ephemeral and dissipate as quickly as they form; other times they persist and grow wide enough to cover a substantial portion of the sky with a sheet of cirrostratus.** Sometimes they maintain their initial integrity as a line of cloud formed in the wake of the rapidly moving aircraft: at other times they develop a series of pendules from which streamers of precipitation are observed to fall.

Contrails are a fascinating subject for study, sufficiently complex to challenge the expert and sufficiently variable to intrigue the amateur observer. Properly understood they yield a wealth of information about the current state of affairs in the high atmosphere, where it is difficult in locate weather instruments. Observed systematically, as a function of time, **contrail information is a valuable adjunct to forecasting the weather.**

Chapter 2 explained that a cloud forms when the moisture content of the air at a particular temperature exceeds a critical amount and that this condition can be attained in 2 ways: (1) adding water vapor to the air from an external source, or (2) cooling the air, thus reducing the amount of moisture it can hold. A second important fact that was discussed (and is illustrated in Appendix 16) is that at a given temperature, slightly more water vapor can be held over a water surface than over an ice surface.

It is easiest to consider the contrails laid down by commercial jets that commonly fly from 10 km to 13 km (32,800-42,600 ft.) where the temperatures ranges from -30°C to -65°C (—22°F to — 85°F). This is the region of the high troposphere or the low stratosphere, it takes very little water at these temperatures to produce a condition of saturation or supersaturation. Between these extremes lie all the possibilities for the many variations in pattern that occur. Moisture at high elevations often advances through the sky in tongues or uneven patterns, both large and small. **Thus contrails may be seen in uneven segments of growth and dissipation.**

Sometimes the multiple **contrails that persist will break into a series of swirled loops,** with the loops joining into ovals. When these loops and connected vortices develop, they ordinarily do not last more than a minute or so. When trails last for longer periods. they may break into a series of pendules or fingers. The pendule is a form of ring vortex, indicating the presence of locally stable moist air. Sometimes pendules are pulled away into long streamers by a zone of faster moving air. **The resulting shear motion may result in such an extensive cloud sheet that the sky becomes completely overcast.**

Contrails are spectacular in early morning and evening, and even in the light of the full moon. When the air to the west is clear and the sun has set, a jet aircraft at 12 km (about 40,000 ft.) will still be illuminated by the sun. Sometimes the white contrail will assume a brilliant red or orange color. To the uninformed, the moving trail, **produced by a plane that is invisible** or appears only as a rapidly moving spot in the sky. may seem to be an out-of-this-world appari-

tion. **More than one such case has subsequently been headlined in the papers as a UFO with a fiery tail.**

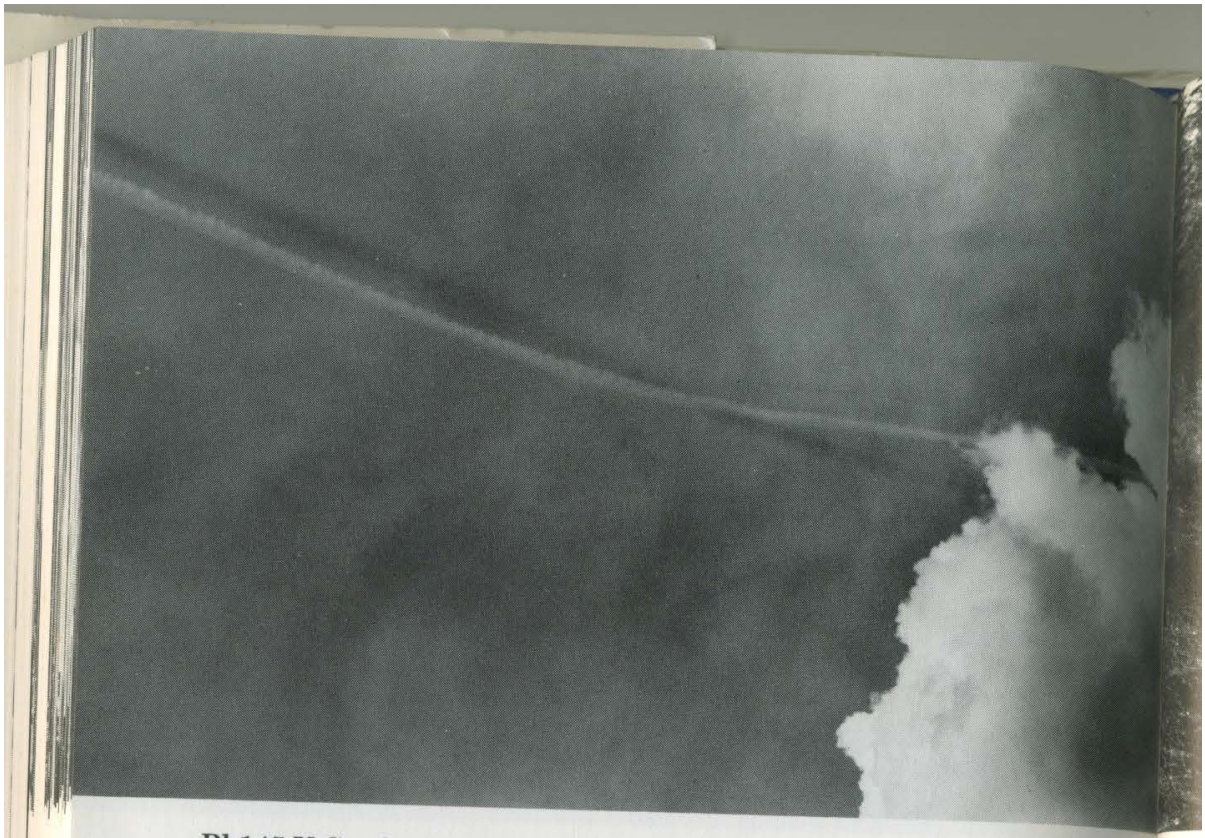
Under most conditions a contrail is made of ice crystals. Though it initially consists of liquid water droplets in the warm exhaust air, these soon change to ice particles in the frigid temperatures of the high atmosphere. The presence of ice is best illustrated when the contrail is located between the observer and the sun. Bright areas called parhelia (see Color Plate 11) are visible at an angle of 22° on either side of the sun. This angle can easily be checked with a built-in device possessed by every human. With arm and fingers outstretched, let the thumb obscure the sun. The little finger, stretched to the maximum, then subtends an angle of about 22°. The bright spots observed are a portion of the well-known 22° halo (see p. 158).

The jet aircraft disturbs its environment in 2 important ways. First, **a jet engine consumes large quantities of fuel, and substantial amounts of water vapor, a major by-product of combustion, leave the engine as one component of the exhaust gases.** Second, the rapid movement of the air over the wings and body of the aircraft generates vortices that persist for a time until their internal energy is dissipated.

The particular contrail pattern will he determined by several interacting factors. These are: (1) the moisture content of the air, (2) the temperature of the air, (3) the moisture introduced into the air by the engines (4) the vertical stability of the air below, at, and above the aircraft. (5) the cloud condensation and ice nuclei count when the air is warmer than -40°C (-40T), and (6) the mixing that takes place between the environmental air and the exhaust.

At one extreme, the air through which the jet is flying might be gently sinking over a large area, and thus have a very low relative humidity. In this case, the addition of moisture might be insufficient to produce anything but a very short-lived contrail, quickly destroyed by mixing with the dry surrounding air. **When a jet passes and leaves no contrails in the sky, or contrails that quickly disappear, this is a good prognosticator of fair weather.**

At the other extreme, the jet flies through air that is gradually rising and becoming cool, and so may be nearly saturated. The addition of moisture from the jet exhaust may then be enough to produce saturation and consequent water drops or ice crystals. **A persistent trail is an indicator of moist air, which may be the first sign of an extensive storm area moving into the region.** This is particularly true when cirrus clouds are also present.



Pl.145 V Condensation trail from a jet plane that produces its shadow on a diffuse mass of ice crystals extending downward below the contrail and the sun.

Pl.146 The condensation trail of a jet plane that is growing where moist air is supersaturated with respect to ice. This shows that the contrail is located below the thin streamers of cirrus cloud.

Pl.173 Ice crystals falling from a condensation trail left by an airplane. Since most contrails form at temperatures colder than −40°C (−40°F), their moisture quickly generates ice crystals.

Pl.174 Condensation trails made by jet aircraft — training or testing flight. Passenger planes rarely deviate in their course except in a holding pattern.