Soviet designer Tupolev describes hydrogen fuel safety measures

Hydrogen-fuelled aircraft flies
The Tupolev Tu-155, a modified Tu-154 fuelled 1>
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Above From Flight, May 7, 1988. Below The modified NK 88 turbofan

Fundamentally new design and
operating procedures have had
to be adopted to enable the
experimental Tupolev Tu-155
airliner to use volatile, highly
explosive liquid hydrogen fuel,
which has to be carried under
pressure at extremely low (cryo-
genic) temperatures, says the
Soviet design bureau.
General designer Alexei
Tupolev tells Flight that exten-
sive ground-rig tests preceded
last year's flight trials of the
highly modified Tu-154 trijet.
The aircraft has a hydrogen-
fuelled Kuznetsov NK88
turbofan in its starboard nacelle.

Leak peril
Tupolev describes the research
programme as the "practical
beginning of cryogenic avia-
tion". He says that, in contrast
to conventional kerosene fuel
systems, any leak or depres-
surisation results in almost
instantaneous vaporisation of
the liquid hydrogen, which
rapidly fills the entire compart-
ment and ignites from the
minutest spark, even at
extremely low vapour concen-
trations.
This radically changes the
concept of inflammability and
fire safety, says Tupolev,
because all wiring and electrical
devices aboard an aircraft
become potential ignition
sources. Tupolev has therefore
"contained" the hydrogen fuel
tank, the fuel-feed control
system, and the engine feed
pipes between bulkheads in the
Tu-155 fuselage. The compart-
ment formed between the bulk-
heads is then pressurised to a
higher level than the vapour
pressure within the fuel tank.
"Spark arresting equipment"
is fitted in the buffer compart-
ment, while information
systems provide the crew with
"timely warning" of any hydro-
gen vapour escaping into it,
"and thus prevent fatal
accidents", according to
Tupolev. The starboard nacelle
is also "contained", and has
spark arresting equipment
installed. The engine fuel-
control systems and feed pipes
are mounted within a stainless-
steel "hydrogen gadget
container" installed in the
upper section of the nacelle.
Flight and emergency vent
pipes exit above the tailplane,

while the hydrogen jettison pipe
leads out through the aircraft
skin and down to the centre
engine nozzle, where it ignites
like gas from the flare stack of
an oil rig.
As a fire precaution, all of the
aircraft's hydraulic pipes,

kerosene fuel lines, and elec-
trical wire bundles are laid
beneath covers on the exterior
skin of the fuselage, and are
ventilated by the airflow during
flight. They are covered with
sealant where they pass through
the skin.

Alexei Tupolev asserts that
liquid hydrogen has a calorific
value three times that of
kerosene, and that it can soon be
produced in sufficient quan-
tities for aviation purposes at
acceptable cost. He says that the
difficulties of using hydrogen as
aircraft fuel made it "highly
advisable" to conduct a
"practical verification" with the
Tu-155. The flight trials
enabled systems failures to be
simulated, and intensive
manoeuvres to be undertaken at
a wide range of aircraft speeds
and altitudes.
Besides the fire problem, the
biggest difficulty is the necessity
to work at cryogenic tempera-
tures. Kerosene requires no
thermal insulation of tanks or
pipes, and neither congeals nor
boils under normal circum-
stances. Because liquid hydro-
gen boils at -253°C, it needs
special insulation. Despite this,
the fluid is permanently boiling
aboard the aircraft, so it is also
necessary to maintain a high
pressure in the tank to minimise
vapour losses through the vents
at high altitude.

Fuel feed

The Tupolev design team has
not attemped to feed hydro-
gen to the engine in liquid
form because vaporisation in
the fuel pipes makes it
extremely difficult to ensure
stable flow and regulate com-
bustion. Instead, the fuel is
deliberately vaporised by raising
its temperature to -170°C in a
heat exchanger before it is fed
to the injectors.
Because liquid hydrogen is
only a quarter as dense as
kerosene, it is practically impos-
sible to accommodate it in the
wings: "hence the need to
develop light but strong fuse-
lage tanks", according to
Tupolev. He says that the rear-
fuselage installation used in the
Tu-155 proved "simple
enough" because the experi-
menters chose an aircraft with a
large cabin, which was required
to carry sufficient fuel only for
sorties of up to lj hr.
Before the Tu-155 flew, the
hydrogen tank, the fuel-feed
system, and the engine were
tested on a rig mounted inside a
giant cryostat. A second
"sophisticated" rig checks out
the fuel-tank pressurisation.

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