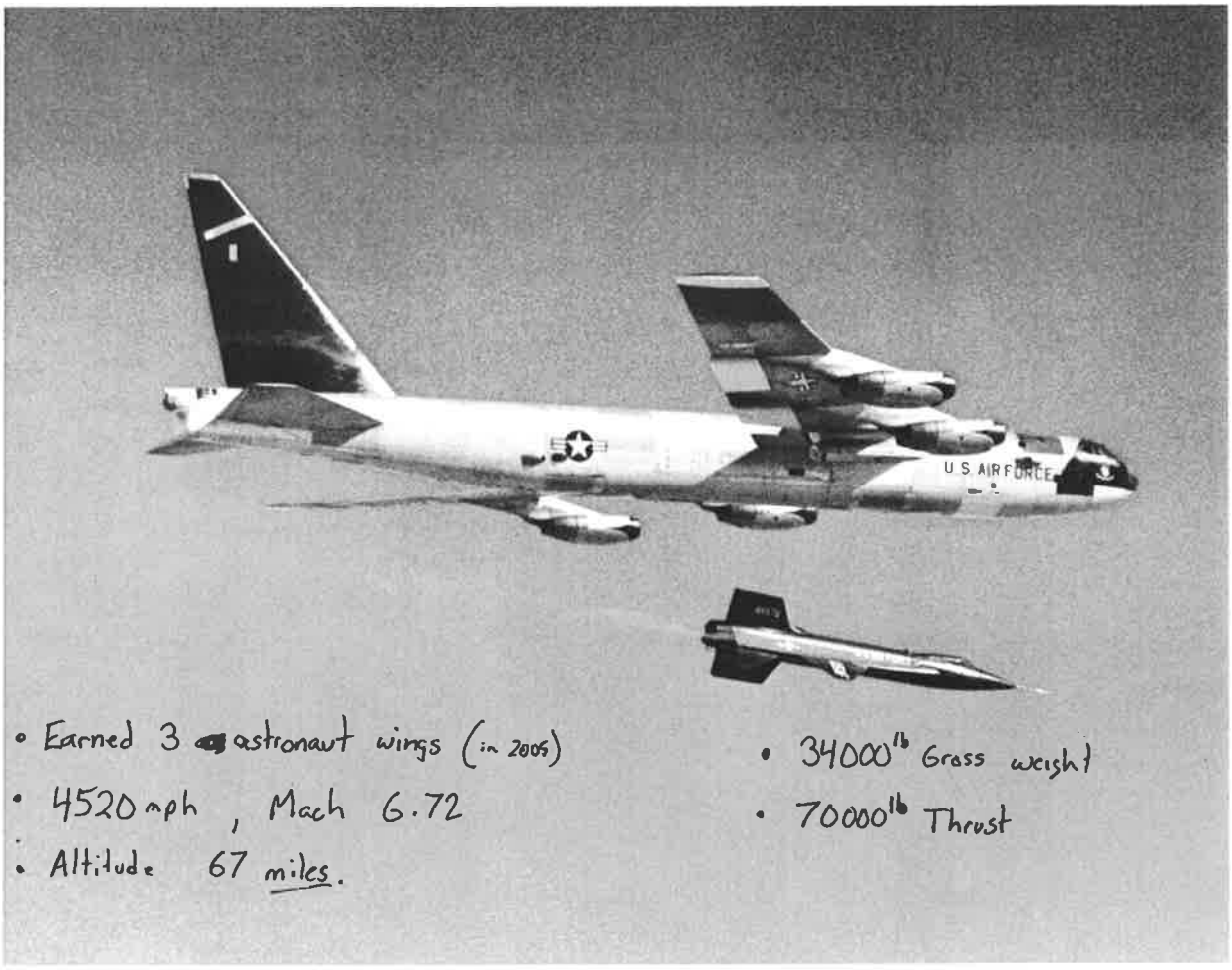
AEM 617 Case Study: X15

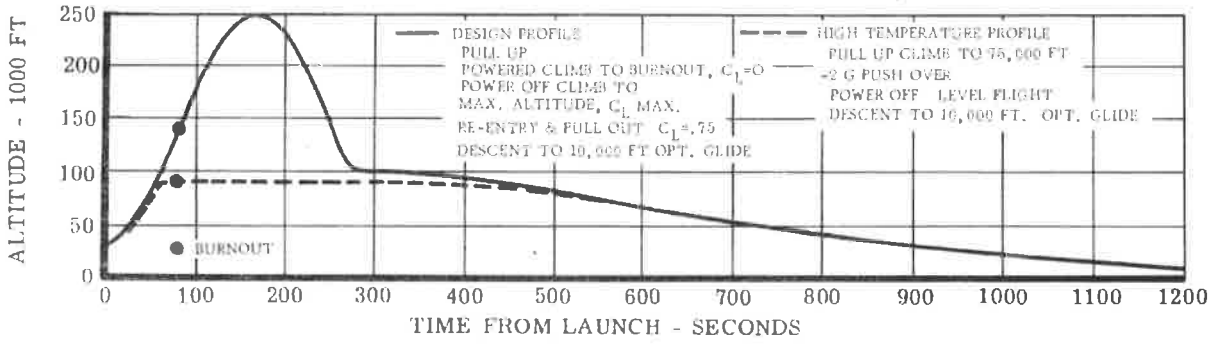
X-15 in Flight Air Force Photo Date Unknown

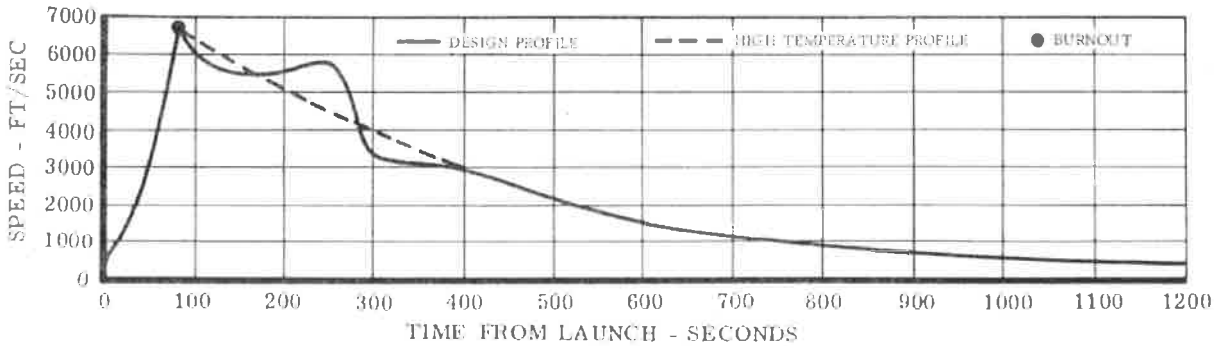
1960's documentary
http://tiny.cc/AEM617X15

Primary Data Source: X-15 Flight Manual
T.O. 1X-15-1
29 December 1961



- Earned 3 astronaut wings (in 2005)
- 4520 mph, Mach 6.72
- Altitude 67 miles.
- 34000 lb Gross weight
- 70000 lb Thrust

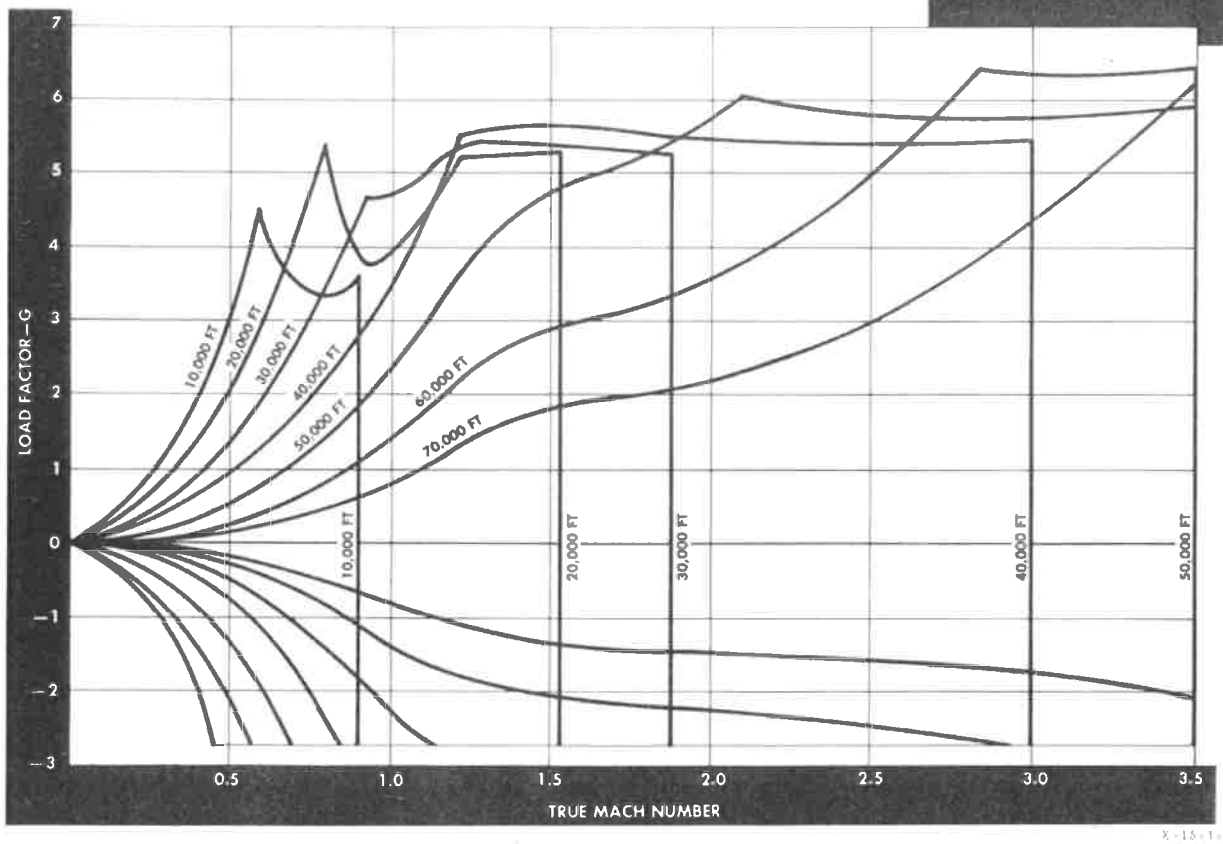




1 OPERATING FLIGHT LIMITS

SYMMETRICAL FLIGHT

CONDITIONS:
GROSS WEIGHT – 20,000 LB.
FLAPS AND GEAR UP



T.O. 1X-15-1 Section II

1 LANDING PATTERN (LOW SPEED—LOW ALTITUDE)

NOTE

- Before landing, preferably on the downwind leg of the landing pattern, but in no case above 17,000 feet above sea level, move vent, pressurization, and jettison control lever to **PRESSURIZE**, to prevent sand and dust from entering the airplane propellant system during landing. The altitude limitation is necessary to preclude structural deformation of the airplane propellant tanks due to a pressure differential which would tend to collapse the tanks.
- To ensure safe recovery of the ventral, the ventral should be jettisoned 1500 feet above the terrain.

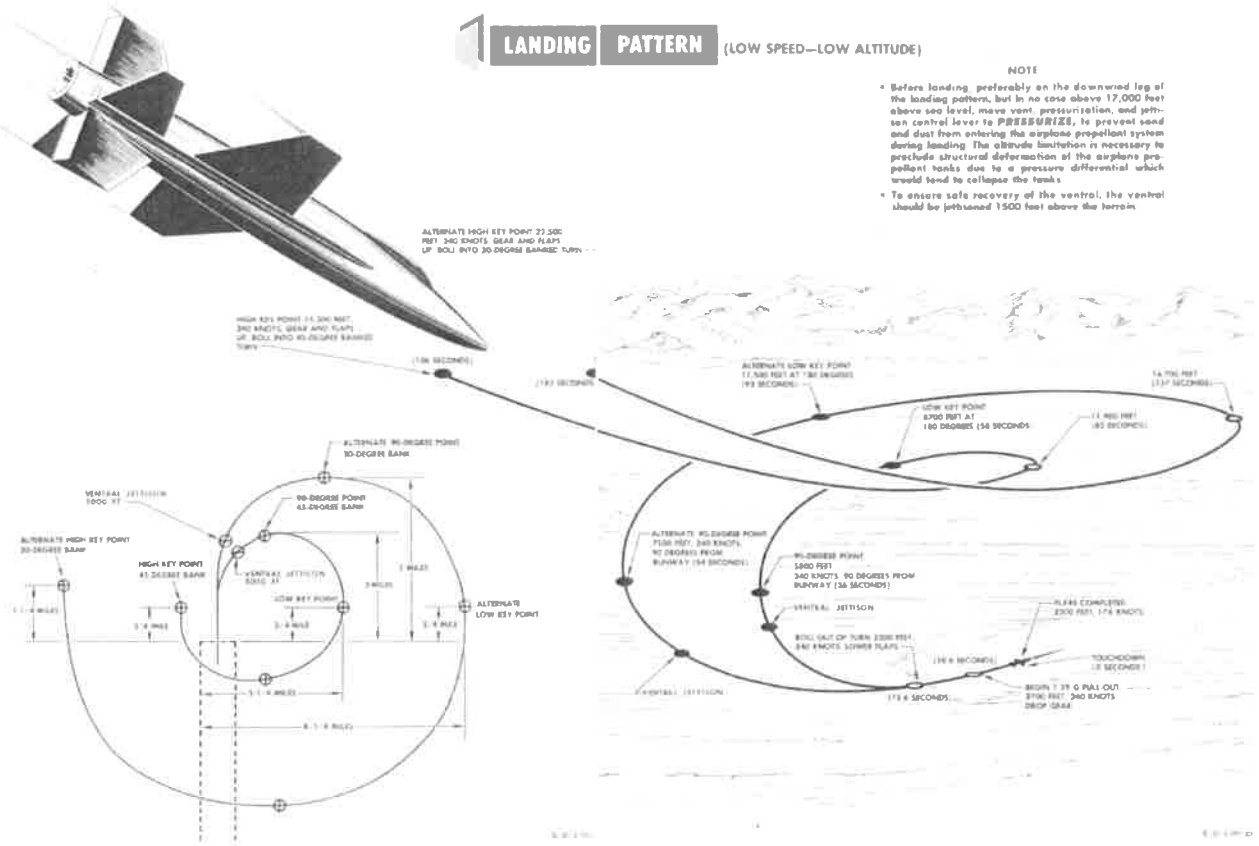
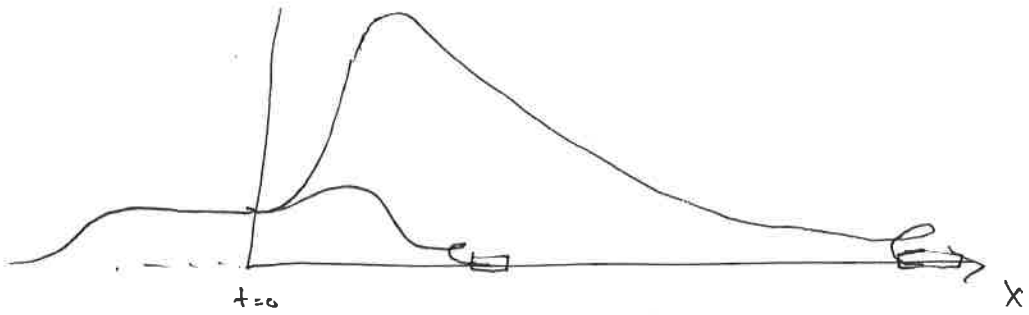


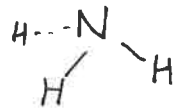
Figure 2-8



Rocket Fuel

Anhydrous Ammonia NH_3

Boils at -28^F

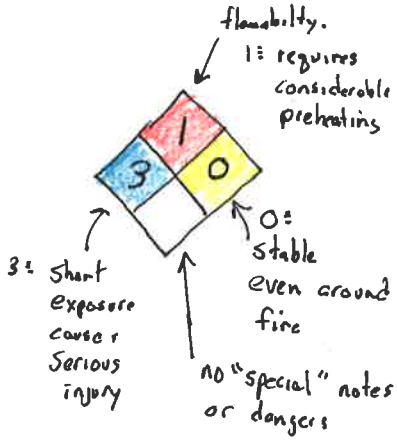


LOX → O_2

$O=O$

Boils at -297^F

Strong oxydizer!



Combustion:

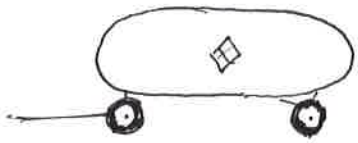
$$4NH_3 + 3O_2 \rightarrow 2N_2 + 6H_2O$$

$$\Delta h = -1267 \frac{kJ}{mol}$$

"Combustion of NH_3 in air is very difficult ... the temperature of the flame is lower than the ignition temp" Wikipedia.

Aside:

NH_3 is used as a fertilizer. If you have ever seen a large white pressure tank on wheels in a field, this is crop fertilization tank.

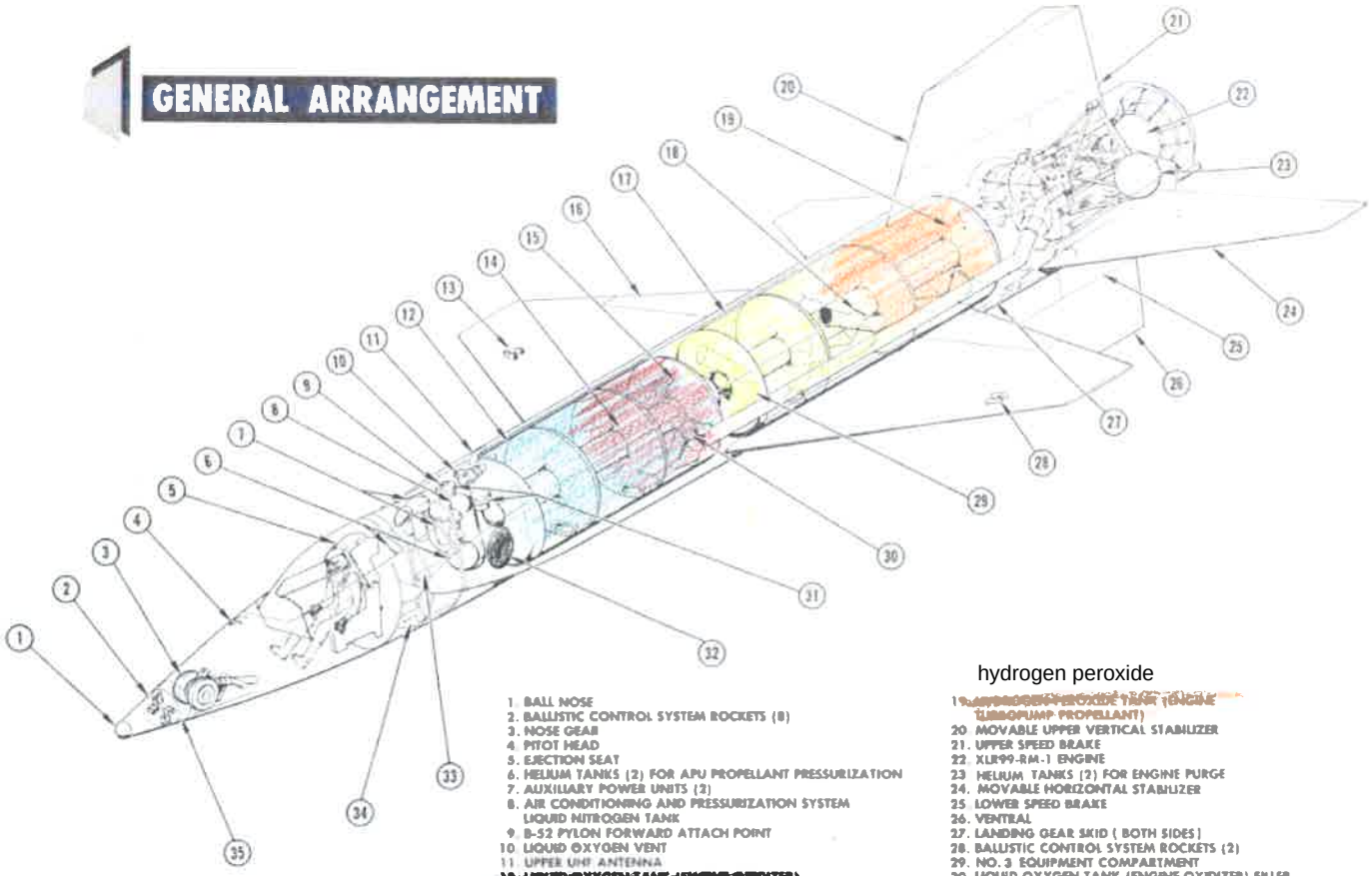


~~Aside~~ Design Concept.

Half as much energy ~~per mass~~ density as traditional hydrocarbons. Why NH_3?

- flamability / unstable
- No soot
- $\rho_{O_2 liq} \approx \rho_{NH_3 liq}$ thus little to no cg shift.
- Relatively low pressure tank and easy to jettison

1 GENERAL ARRANGEMENT



1. BALL NOSE
2. BALLISTIC CONTROL SYSTEM ROCKETS (8)
3. NOSE GEAR
4. PITOT HEAD
5. EJECTION SEAT
6. HELIUM TANKS (2) FOR APU PROPELLANT PRESSURIZATION
7. AUXILIARY POWER UNITS (2)
8. AIR CONDITIONING AND PRESSURIZATION SYSTEM LIQUID NITROGEN TANK
9. B-52 PYLON FORWARD ATTACH POINT
10. LIQUID OXYGEN VENT
11. UPPER UHF ANTENNA
12. LIQUID OXYGEN TANK (ENGINE OXIDIZER)
13. BALLISTIC CONTROL SYSTEM ROCKETS (2)
14. HELIUM TANK (FOR ENGINE PROPELLANT PRESSURIZATION)
15. HELIUM TANK FOR PRESSURIZATION CONTROL ENGINE CONTROL, AND ENGINE HYDROGEN PEROXIDE PRESSURIZATION
16. RIGHT-HAND WING FLAP
17. AMMONIA TANK
18. B-52 PYLON REAR ATTACH POINT (BOTH SIDES)

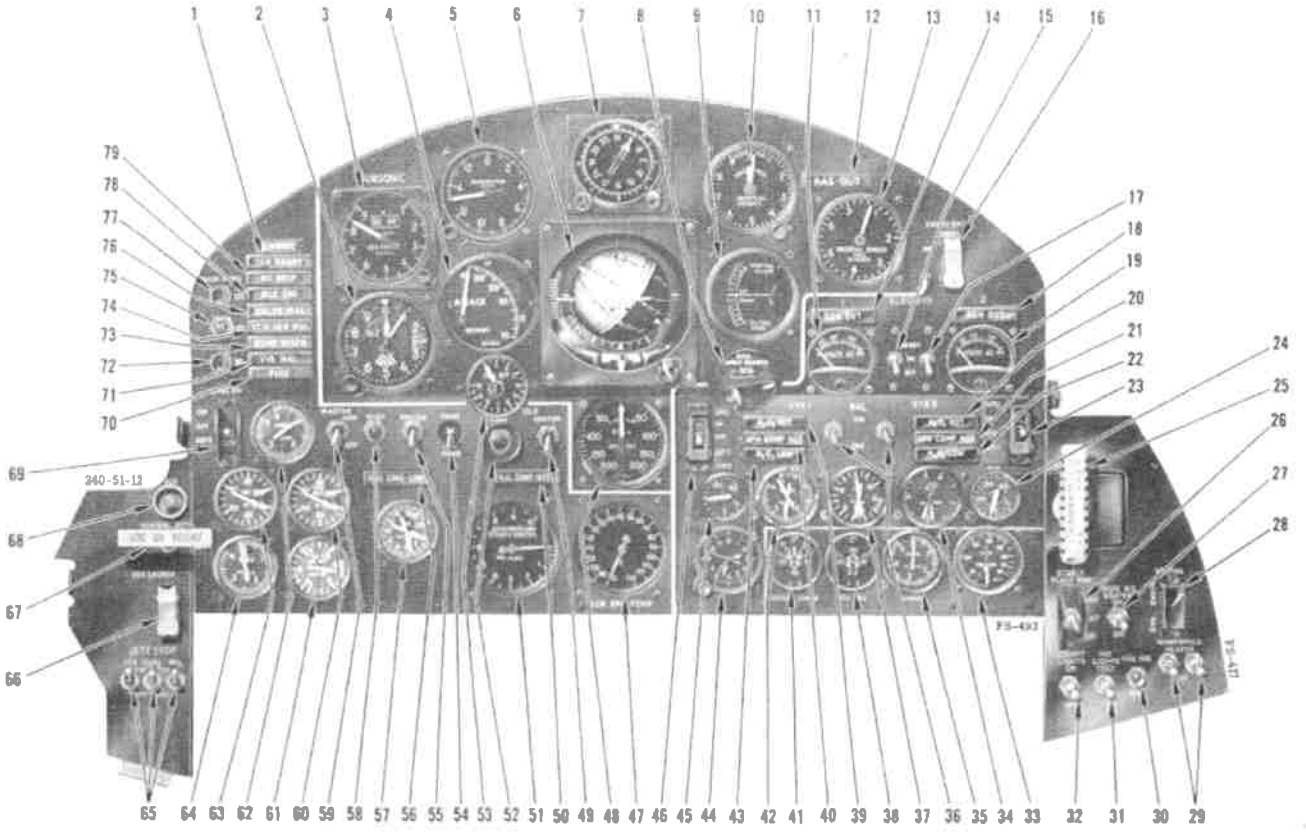
hydrogen peroxide

19. HYDROGEN-PEROXIDE TANK (ENGINE TURBOPUMP PROPELLANT)
20. MOVABLE UPPER VERTICAL STABILIZER
21. UPPER SPEED BRAKE
22. XLR99-RM-1 ENGINE
23. HELIUM TANKS (2) FOR ENGINE PURGE
24. MOVABLE HORIZONTAL STABILIZER
25. LOWER SPEED BRAKE
26. VENTRAL
27. LANDING GEAR SKID (BOTH SIDES)
28. BALLISTIC CONTROL SYSTEM ROCKETS (2)
29. NO. 3 EQUIPMENT COMPARTMENT
30. LIQUID OXYGEN TANK (ENGINE OXIDIZER) FILLER
31. HYDRAULIC SYSTEM RESERVOIRS (2)
32. HYDROGEN-PEROXIDE TANKS (2) APU AND BALLISTIC CONTROL SYSTEMS PROPELLANT
33. NO. 2 EQUIPMENT COMPARTMENT
34. LOWER UHF ANTENNA
35. NO. 1 EQUIPMENT COMPARTMENT

X-15-1-00-1B

1 INSTRUMENT PANEL

Early version: Later version had advanced (for the time) flight monitoring



1 IGNITION-READY CAUTION LIGHT
2 ALTIMETER
3. AIRSPEED INDICATOR
4 ANGLE-OF-ATTACK INDICATOR
5 ACCELEROMETER
6 ATTITUDE INDICATOR
7 AZIMUTH INDICATOR
8 PITCH ANGLE SET CONTROL
9 VERTICAL VELOCITY INDICATOR
10. INERTIAL HEIGHT (ALTIMETER) INDICATOR
11 NO. 1 GENERATOR VOLTMETER
12 RAS-OUT INDICATOR LIGHT
13 INERTIAL SPEED (VELOCITY) INDICATOR
14 NO. 1 GENERATOR OUT LIGHT
15. NO. 1 GENERATOR SWITCH
16 EMERGENCY BATTERY SWITCH
17 NO. 3 GENERATOR SWITCH
18 NO. 3 GENERATOR-OUT LIGHT
19. NO. 3 GENERATOR VOLTMETER
20 NO. 2 APU HYDROGEN PEROXIDE OVERHEAT WARNING LIGHT
21. NO. 2 APU COMPARTMENT OVERHEAT CAUTION LIGHT
22. NO. 2 APU HYDROGEN PEROXIDE-LOW CAUTION LIGHT
23 NO. 2 APU SWITCH
24 NO. 2 HYDRAULIC TEMPERATURE GAGE
25 CANOPY INTERNAL EMERGENCY JETTISON HANDLE
26. STABLE PLATFORM SWITCH
27. NOSE BALLISTIC ROCKET HEATER SWITCH
28 VENTRAL ARMING SWITCH
29. WINDSHIELD HEATER SWITCHES (2)
30 FIRE-WARNING LIGHT TEST BUTTON
31 INDICATOR, CAUTION, AND WARNING LIGHT SWITCH
32 COCKPIT LIGHTING SWITCH
33 CABIN PRESSURE ALTIMETER
34 HYDRAULUC PRESSURE GAGE
35. CABIN HELIUM SOURCE PRESSURE GAGE
36 NO. 1 AND NO. 2 BALLISTIC CONTROL SWITCHES
37 HYDROGEN PEROXIDE TANK PRESSURE GAGE
38 APU BEARING TEMPERATURE GAGE
39. NO. 1 APU HYDROGEN PEROXIDE OVERHEAT WARNING LIGHT
40 NO. 1 APU COMPARTMENT OVERHEAT CAUTION LIGHT
41 MIXING CHAMBER TEMPERATURE GAGE
42 APU SOURCE PRESSURE GAGE
43 NO. 1 APU HYDROGEN PEROXIDE-LOW CAUTION LIGHT
44. CLOCK
45 NO. 1 HYDRAULIC TEMPERATURE GAGE
46 NO. 1 APU SWITCH
47 LIQUID OXYGEN BEARING TEMPERATURE GAGE
48 RATE-OF-ROLL INDICATOR
49 IGNITER IDLE SWITCH
50 H O COMPARTMENT-HOT CAUTION LIGHT
51 CHAMBER AND STAGE 2 IGNITER PRESSURE GAGE
52 TURBOPUMP IDLE BUTTON
53 FUEL QUANTITY GAGE
54 ENGINE PRIME SWITCH
55 ENGINE PRECOOL SWITCH
56 FUEL LINE-LOW CAUTION LIGHT
57 PROPELLANT MANIFOLD PRESSURE GAGE
58 ENGINE RESET BUTTON
59 ENGINE MASTER SWITCH
60 PROPELLANT PUMP INLET PRESSURE GAGE
61 H O TANK AND ENGINE CONTROL LINE PRESSURE GAGE
62 PROPELLANT SOURCE PRESSURE GAGE
63 PROPELLANT TANK PRESSURE GAGE
64 H O SOURCE AND PURGE PRESSURE GAGE
65 JETTISON STOP SWITCHES
66 AUXILIARY LAUNCH SWITCH
67 LANDING GEAR HANDLE
68 VENTRAL JETTISON BUTTON
69 HELIUM RELEASE SELECTOR SWITCH
70 FIRE-WARNING LIGHT
71 ENGINE VIBRATION MALFUNCTION CAUTION LIGHT
72 AMMONIA TANK PRESSURE-LOW CAUTION LIGHT
73 TURBOPUMP OVERSPEED CAUTION LIGHT
74 STAGE 2 IGNITION MALFUNCTION CAUTION LIGHT
75 PROPELLANT EMERGENCY PRESSURIZATION SWITCH
76 VALVE MALFUNCTION CAUTION LIGHT
77 LIQUID OXYGEN TANK PRESSURE-LOW CAUTION LIGHT
78 IDLE END LIGHT
79 NO-DROP CAUTION LIGHT

T.O. 1X-15-1

pressurization
pressurization

H_2 LOX O_2 NH_3

1 ENGINE PROPELLANT CONTROL SYSTEM

NOTE

Liquid oxygen, ammonia, and hydrogen peroxide are supplied to the feed valves under pressure when the vent pressurization, and jettison control lever is placed at **PRESSURIZE.**

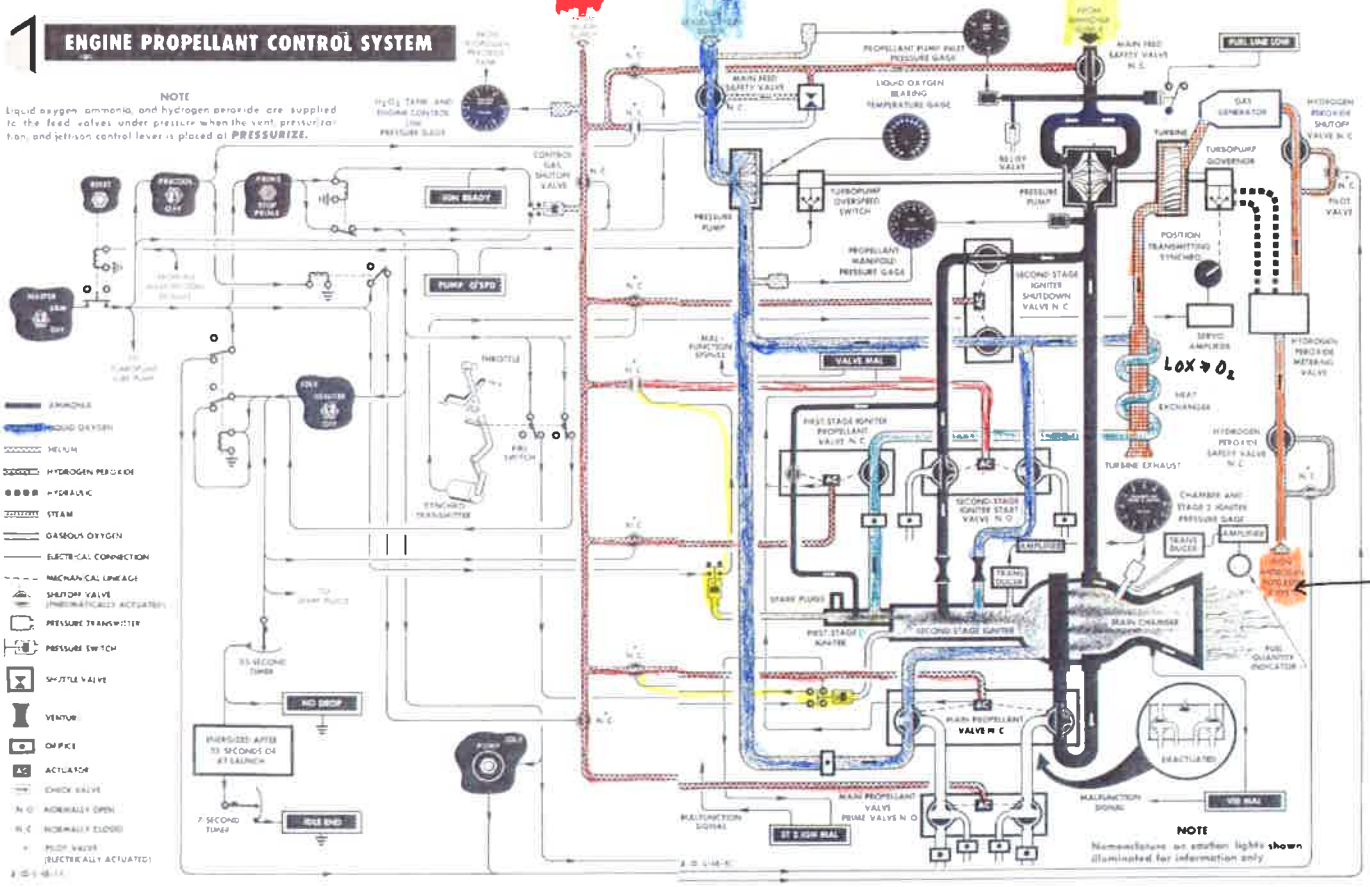
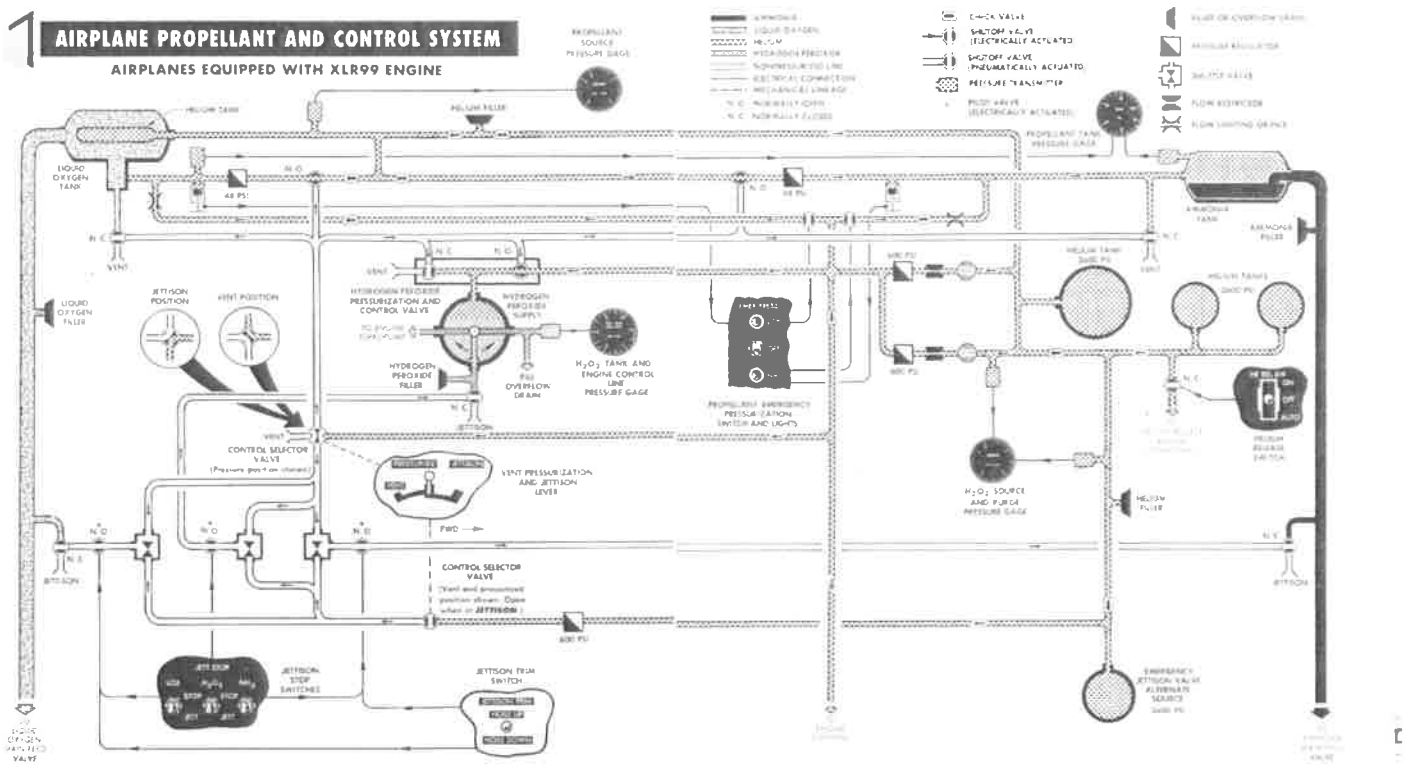


Figure 1-7

T.O. 1X-15-1 Section I

AIRPLANE PROPELLANT AND CONTROL SYSTEM

AIRPLANES EQUIPPED WITH XLR99 ENGINE



NOTE

Move jettison trim switch to ***NOSE DOWN*** to stop liquid oxygen jettison. Move switch to ***NOSE UP*** to stop ammonia jettison.

NOTE

When the vent pressurization and jettison control lever is in the ***VENT*** position all vent valves are open and pressurization and jettison valves are closed. When the lever is in the ***PRESSURIZED*** position, the pressurization valves are open and the jettison and vent valves are closed. When the lever is in the ***JETTISON*** position the jettison and pressurization valves are open and the vent valves are closed.

Figure 1-6

T.O. 1X-15-1

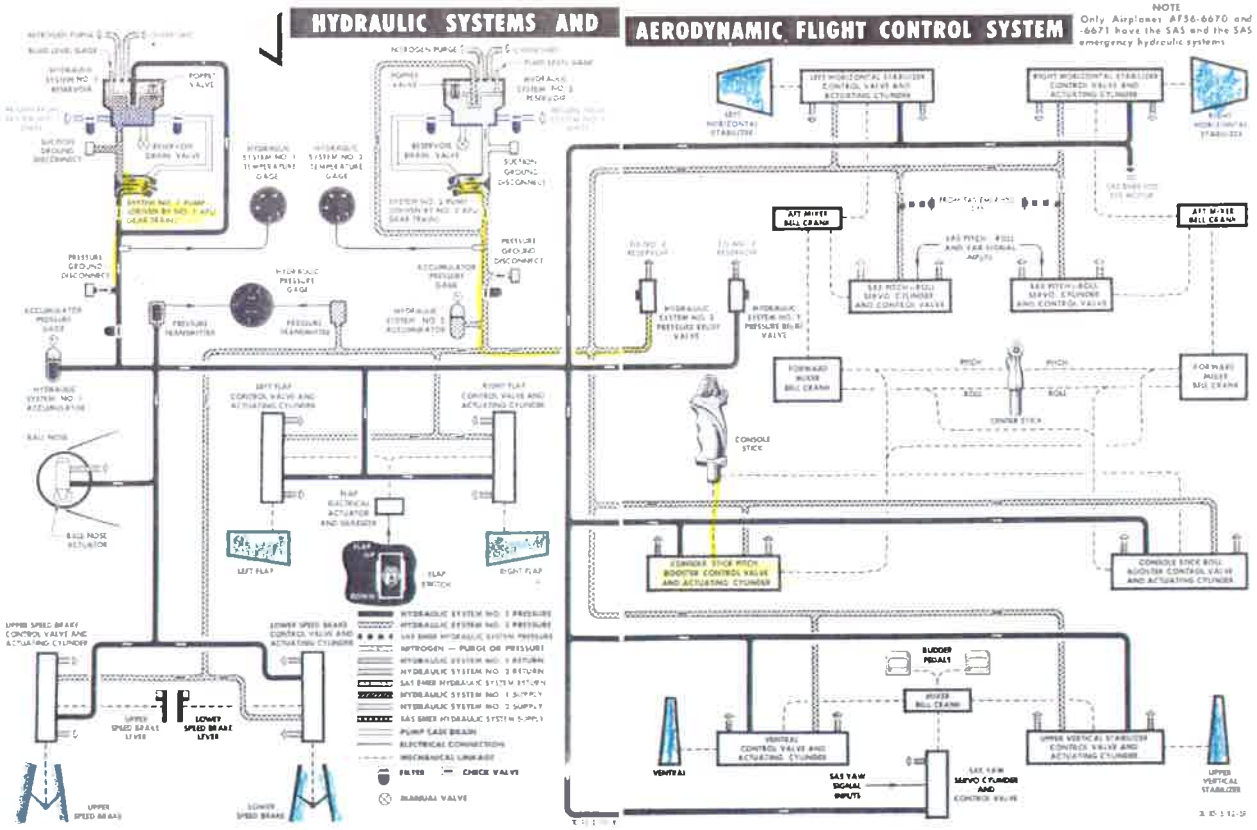
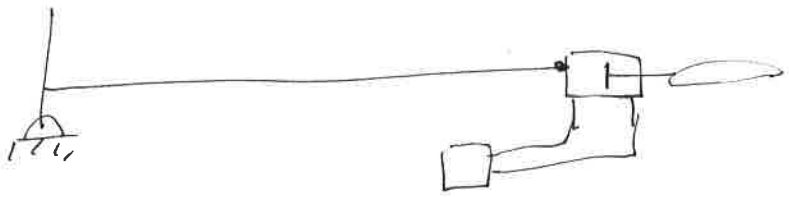


Figure 1-10. (Sheet 1 of 3)

Figure 1-10. (Sheet 2 of 3)



1 CANOPY

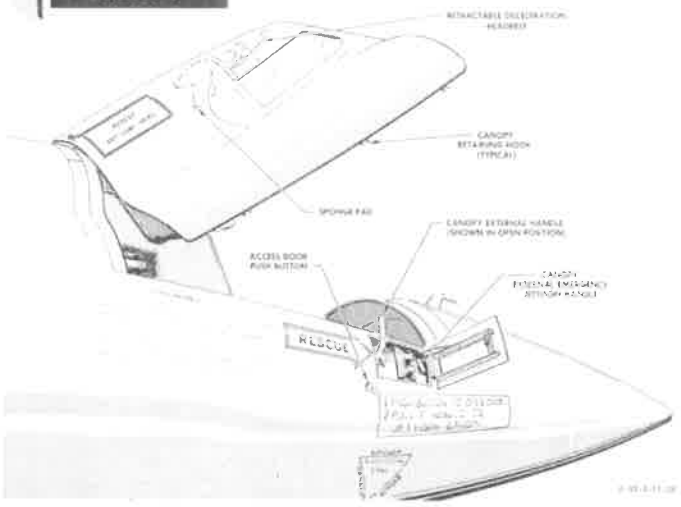


Figure 1-13

1 ENTERING COCKPIT

T.O. 1X-15-1 Section IV

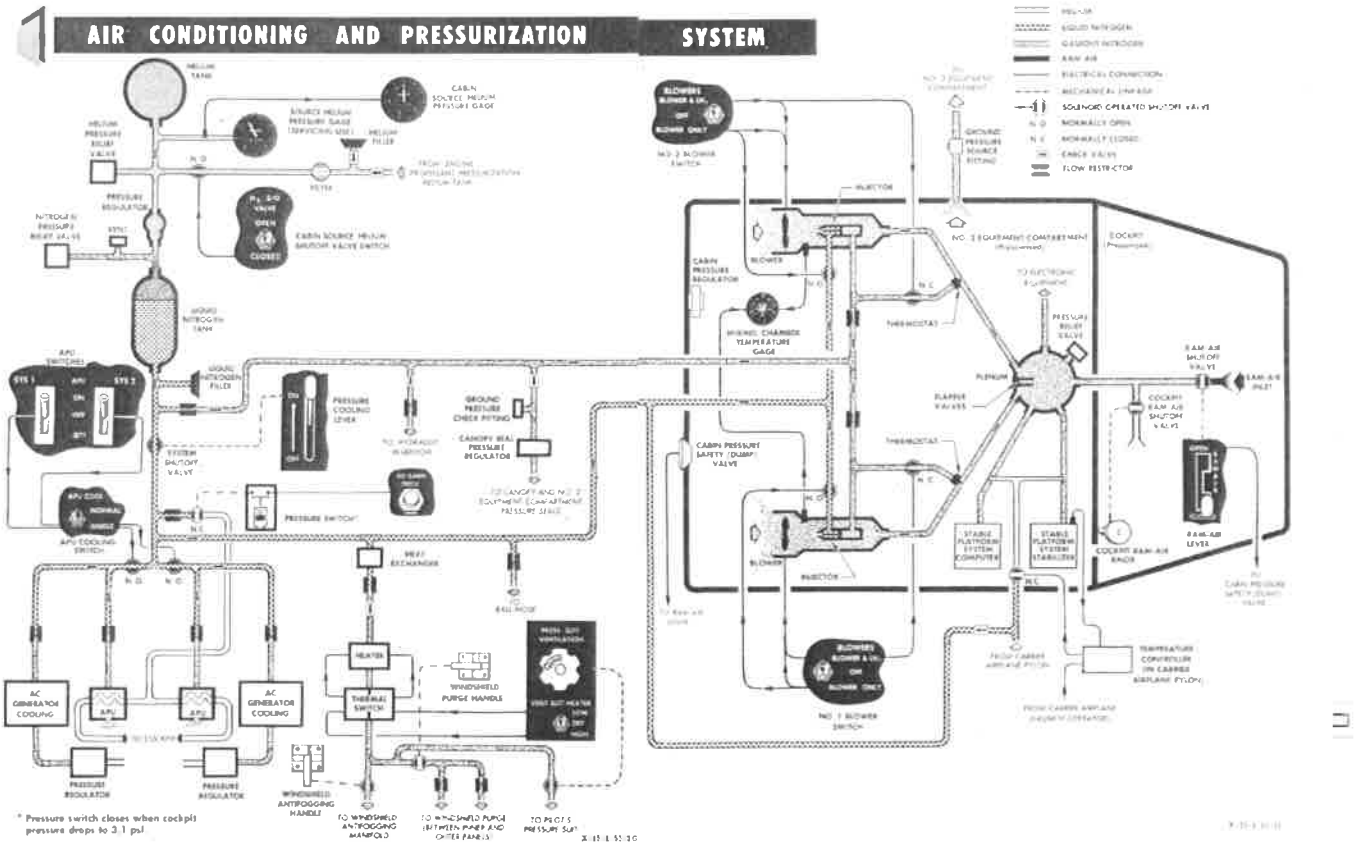


Figure 4-1

Cabin N_2 purged

pilot O_2 mask