# CRYOGENIC FLUID TRANSFER - ORBITAL TRANSFER VEHICLE

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EP6598

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| CHART NO.: | CRYOGENIC FLUID TRANSFER ORBITAL TRANSFER VEHICLE | DATE: JUNE 1982 |

## PRESENTATION OUTLINE

√ **REQUIREMENT OVERVIEW**

- OTV CONFIGURATIONS
  - SIZE RANGE
  - INTERNAL HARDWARE
- GENERAL REFUELING CONCEPT

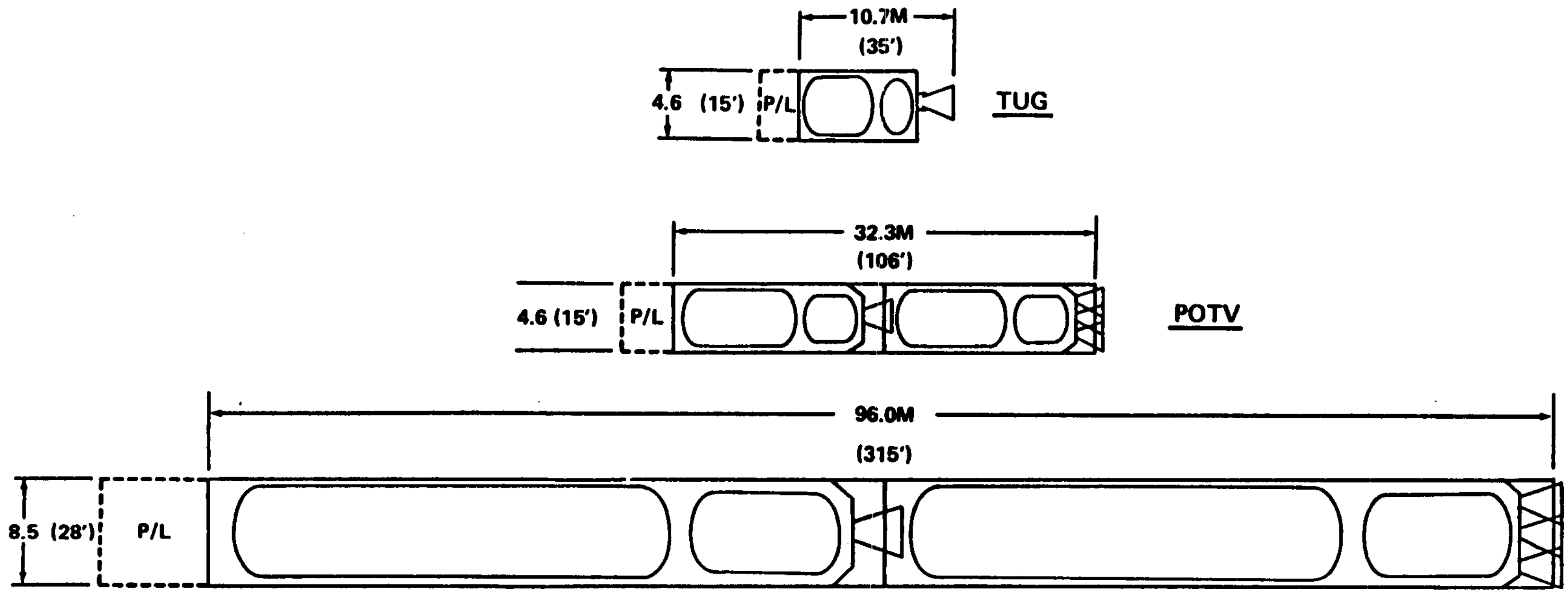
**DESIGN/TECHNOLOGY CONSIDERATIONS**

- TANK CHILLDOWN
  - INITIAL TANK CONDITIONS
  - CHILLDOWN THERMODYNAMICS
- TANK FILL
  - FILL THERMODYNAMICS
  - SUPPLY TANK EFFECTS
- SPECIAL ISSUES
  - RESIDUALS
  - START BASKET OR TANK PRESENCE

**CONCLUSIONS**

EP6558

# OTV CONFIGURATION OVERVIEW

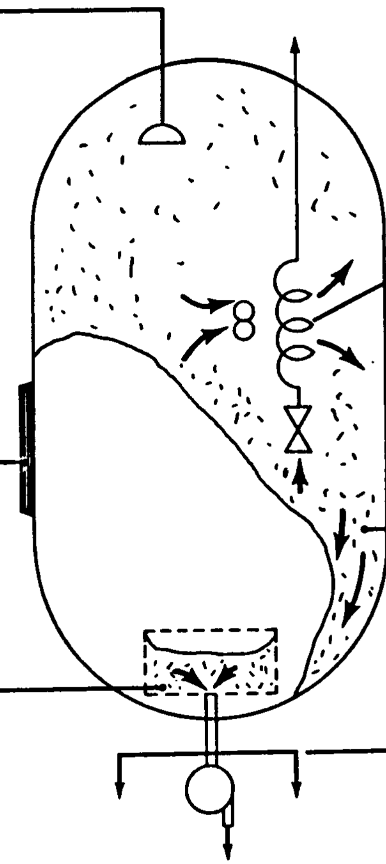





| VEHICLE | PROPELLANT | TANK VOLUME $M^3$ ($FT^3$) | PROPELLANT LOAD KG (LB) | OPERATING PRESS $kN/M^2$ (PSI) | MISSION |
|---|---|---|---|---|---|
| POTV | $LO_2$ | 41 (1450) | 44,550 (99,000) | 172 (25) | 4 MEN FROM LEO TO GEO AND RETURN OR 100K TO GEO AND 60K RETURN WITH GEO REFUELING |
| | $LH_2$ | 116 (4100) | 7,875 (17,500) | 172 (25) | |
| COTV | $LO_2$ | 183 (6460) | 197,400 (438,600) | 172 (25) | 500K FROM LEO TO GEO |
| | $LH_2$ | 549 (19,400) | 37,260 (82,800) | 172 (25) | |

EP4401

# OTV CRYOGEN MANAGEMENT CONSIDERATIONS



EP6559

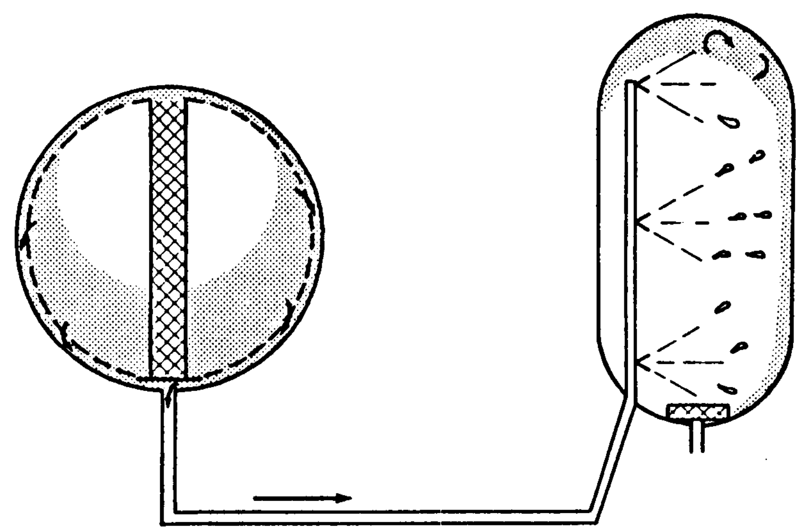
# ORBITAL CRYOGEN TRANSFER CONSIDERATIONS

**SUPPLY TANK**

- STORAGE/VENTING
- ACQUISITION/EXPULSION
  - LIQUID ORIENTATION
  - BOILING/SCREEN DRYING
  - PRESSURIZATION
  - OUTFLOW RATE
  - RESIDUALS

**RECEIVER (OTV)**

- PRECHILL
  - INLET FLOWRATE/DISTRIBUTION
  - WALL CHILLDOWN
- NO VENT FILL
  - NON-EQUILIBRIUM THERMODYNAMICS
  - HELIUM PRESENCE
- START BASKET REFILL
- MASS GAUGING



**TRANSFER LINE**

- CHILLDOWN – PRESSURE SURGES
- FLUID LOADS
  - TRANSIENT
  - STEADY-STATE

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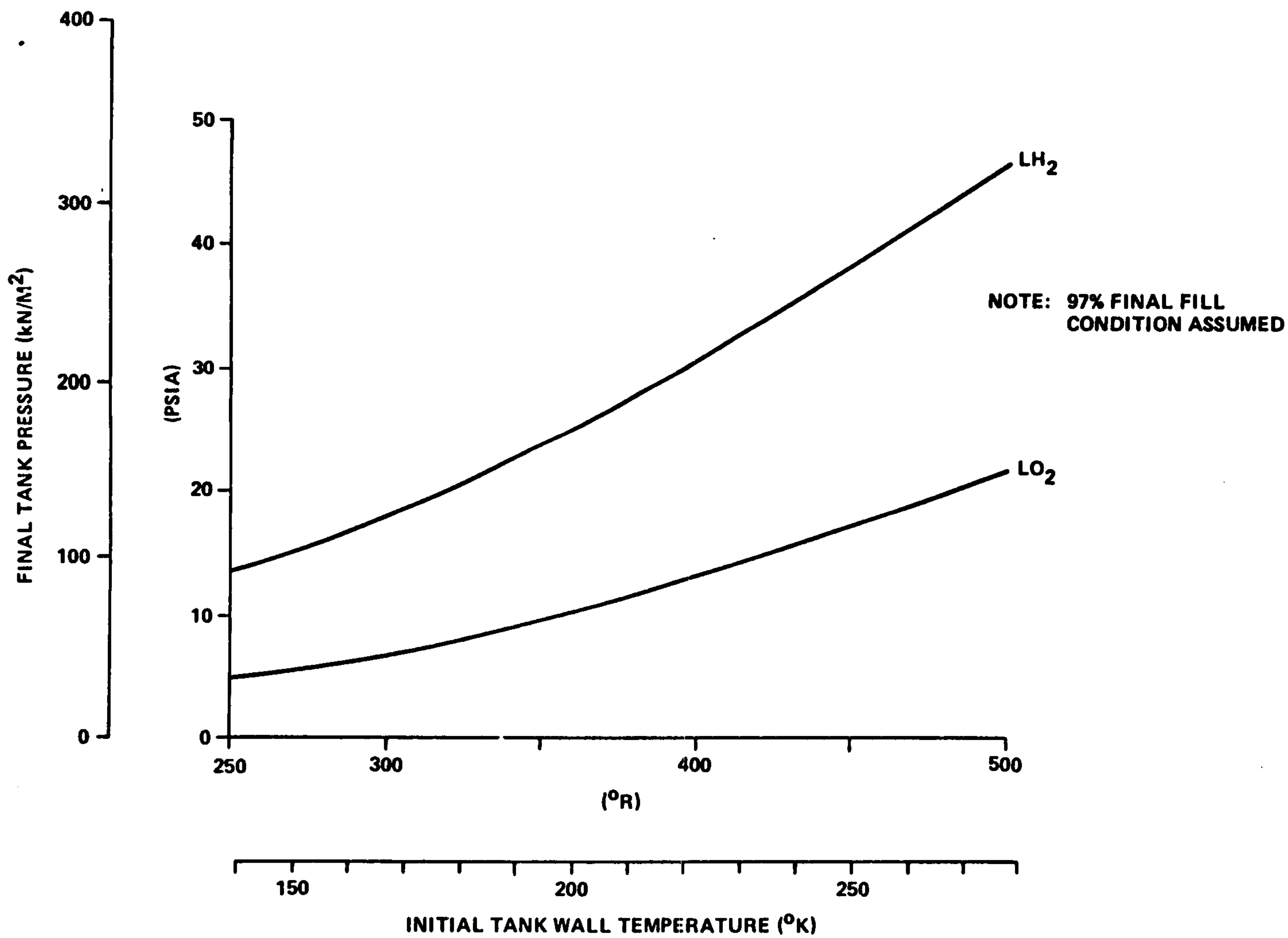
### CONCLUSIONS

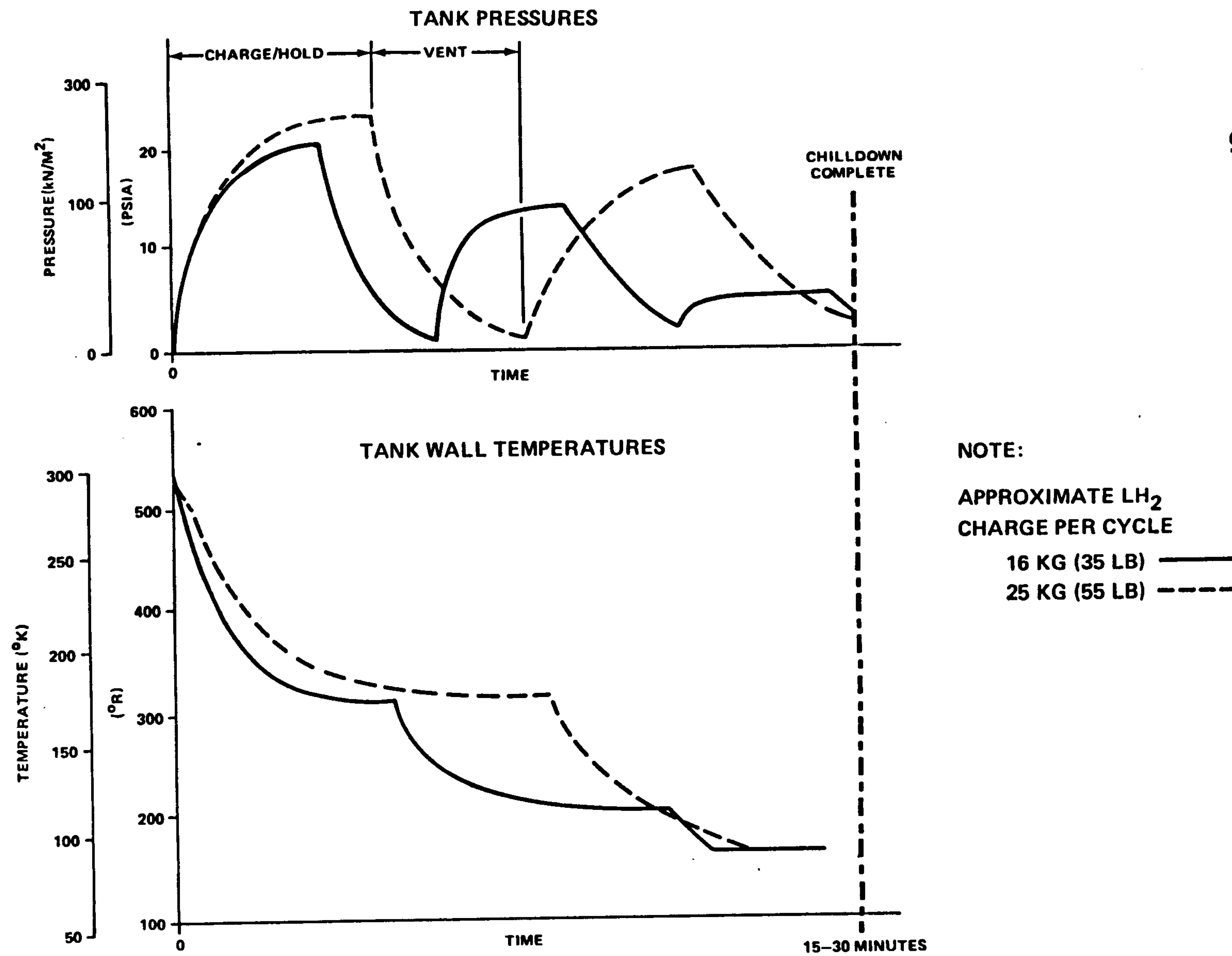
EP6563

# INITIAL WALL TEMPERATURE EFFECTS ON POTV $LH_2$ TANK PRESSURES AFTER FILL



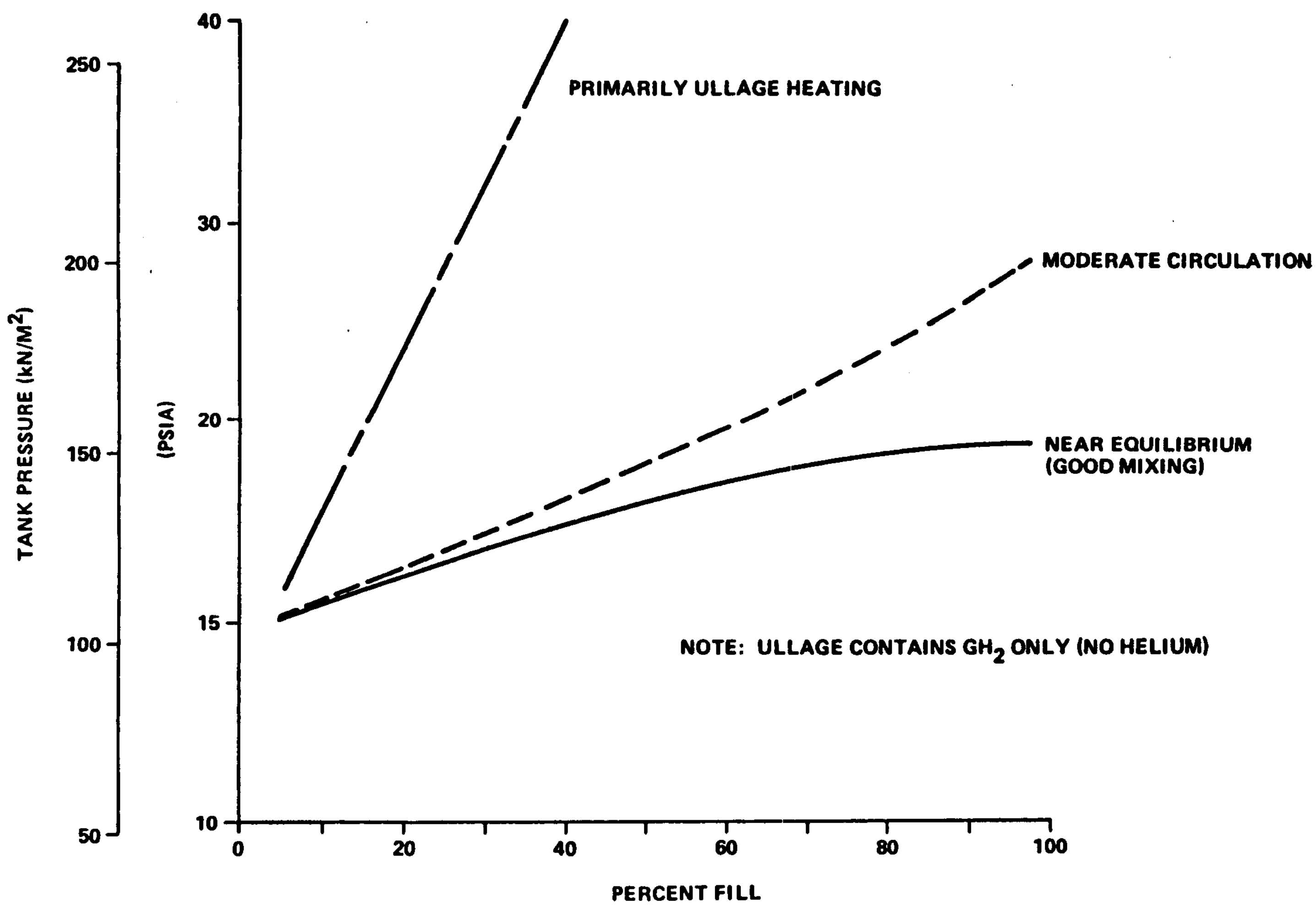
EP6560

# POTV $LH_2$ TANK THERMODYNAMICS DURING CHILLDOWN



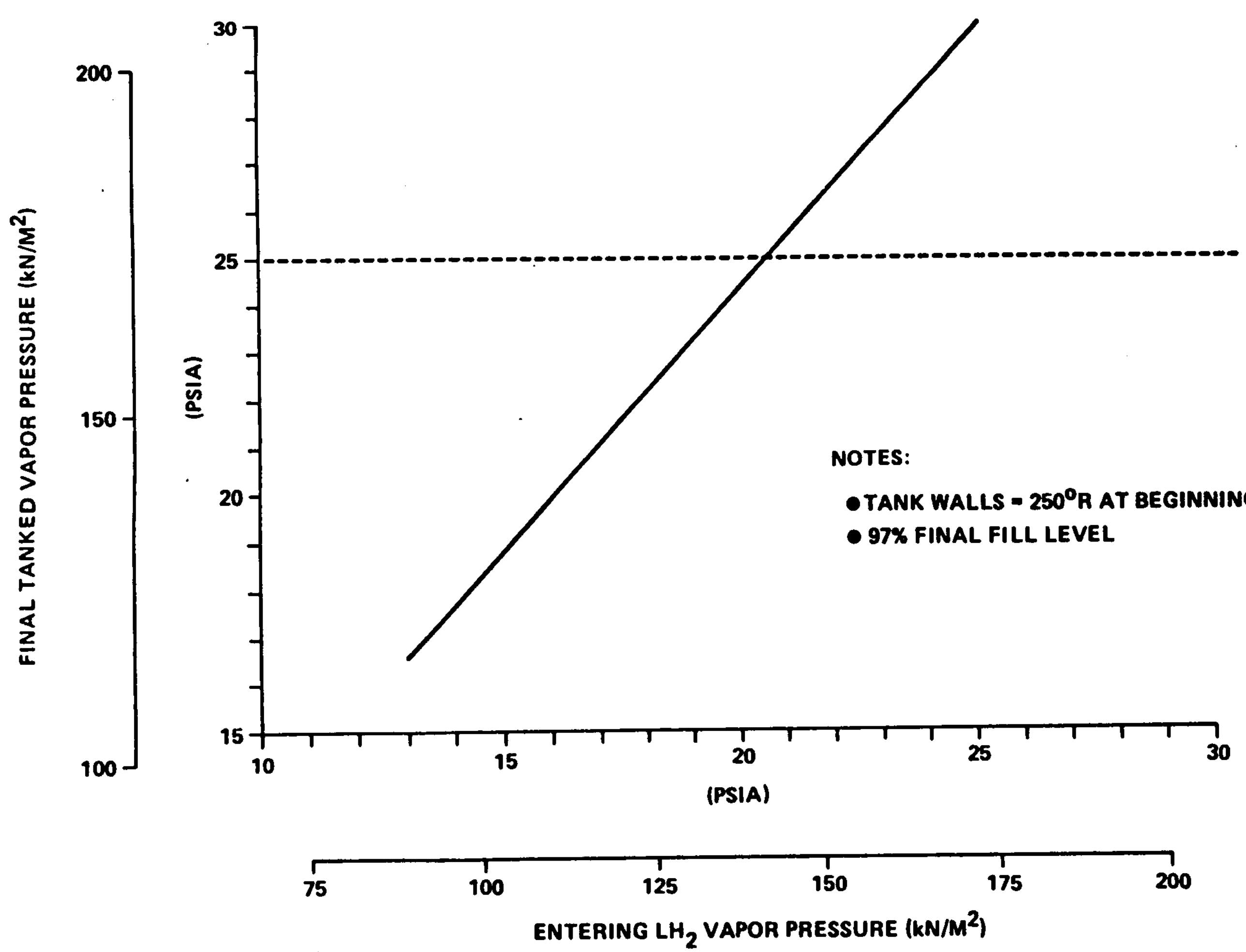
EP6562

# POTV $LH_2$ TANK PRESSURES DURING ORBITAL FILL



EP6564

## ENTERING $LH_2$ VAPOR PRESSURE EFFECTS ON POTV TANK PRESSURE AT FILL COMPLETION

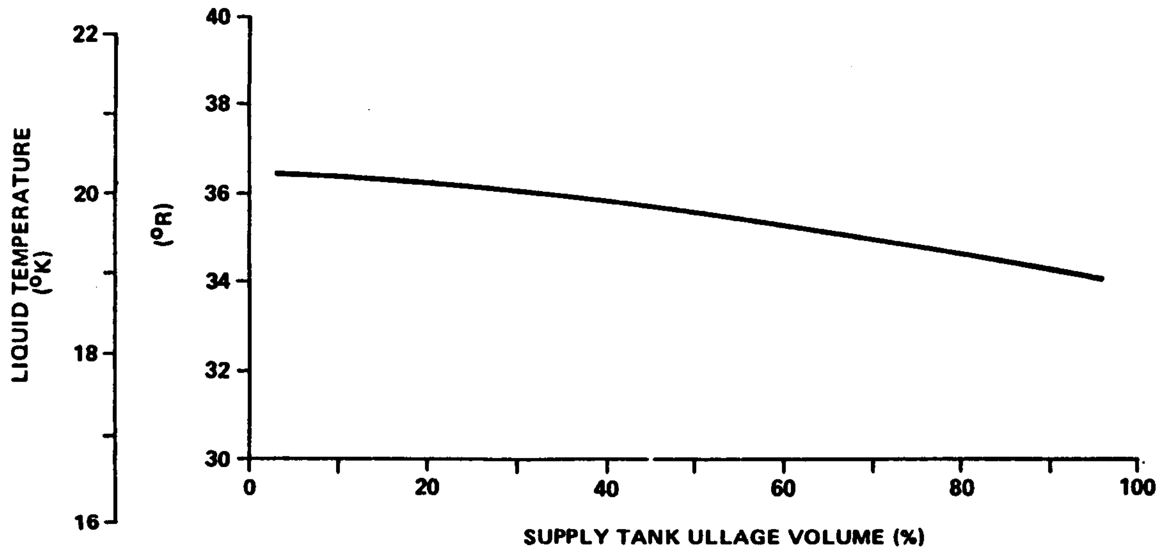


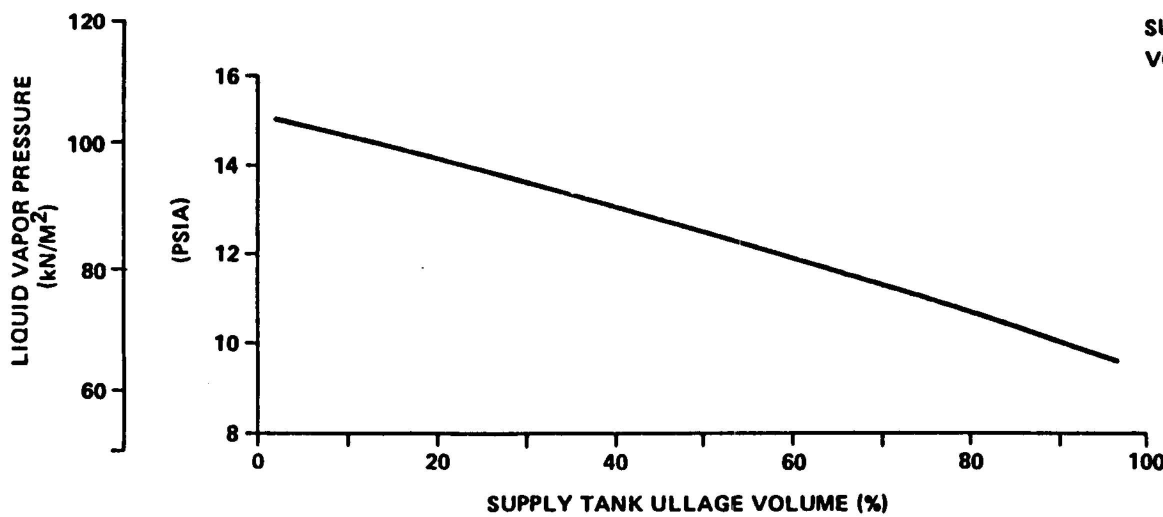

NOTES:

- TANK WALLS = 250°R AT BEGINNING OF FILL
- 97% FINAL FILL LEVEL

EP6561

# $LH_2$ SUPPLY TANK THERMODYNAMIC CONDITIONS



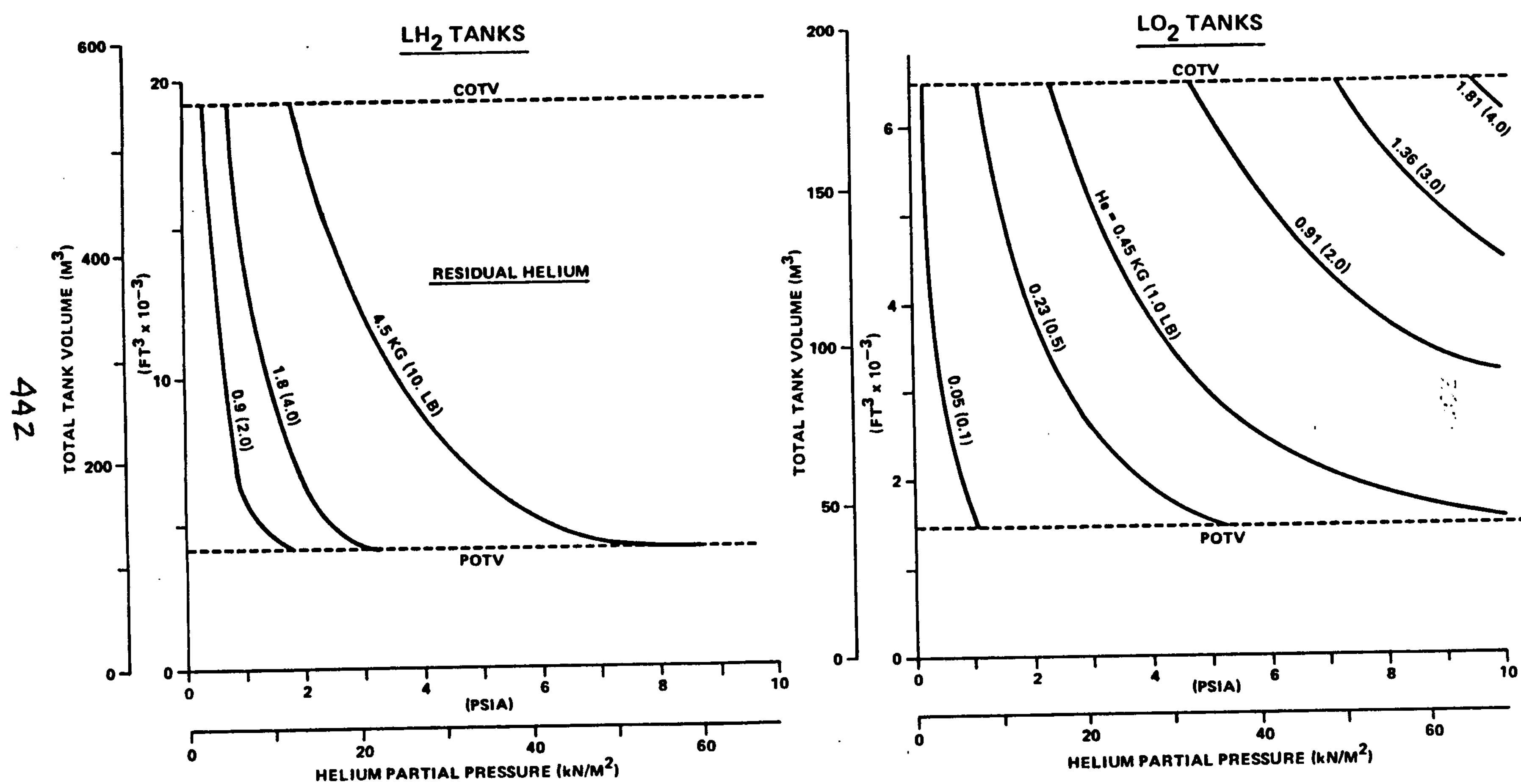




NOTE:

SUPPLY TANK VOLUME = $85 M^3$ ($3000 FT^3$)

EP6566

# RESIDUAL HELIUM PARTIAL PRESSURES AT 97% FILL LEVEL

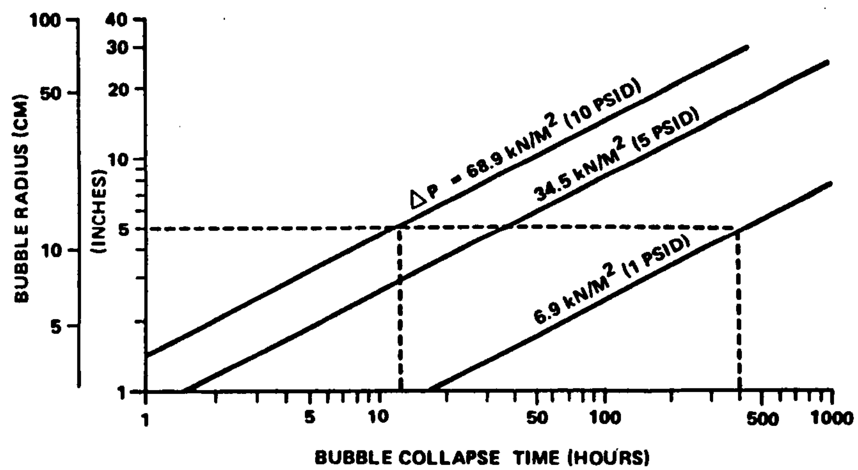


EP6565

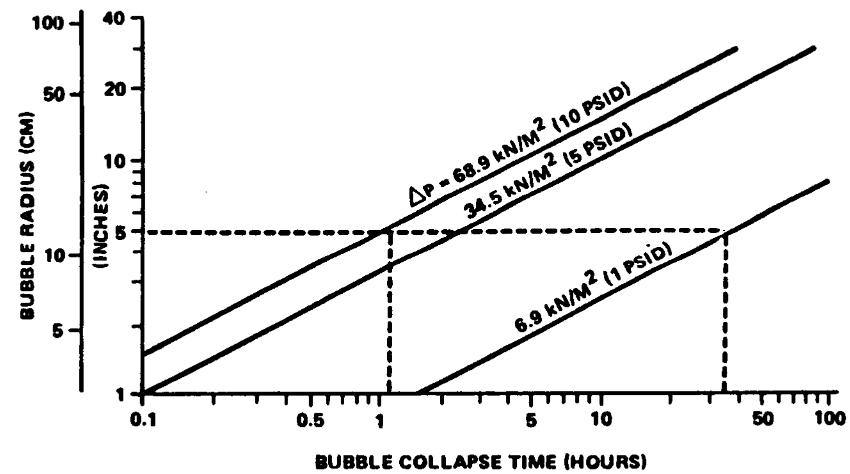
# PROPELLANT BUBBLE COLLAPSE BY INCREASING ULLAGE PRESSURE



## LIQUID HYDROGEN




## LIQUID OXYGEN




NOTE: Δ P = ULLAGE PRESSURE – SATURATION PRESSURE

CONCLUSION: COLLAPSE OF BUBBLES IN START BASKETS COULD REQUIRE ACTIVE CIRCULATION

EP6600

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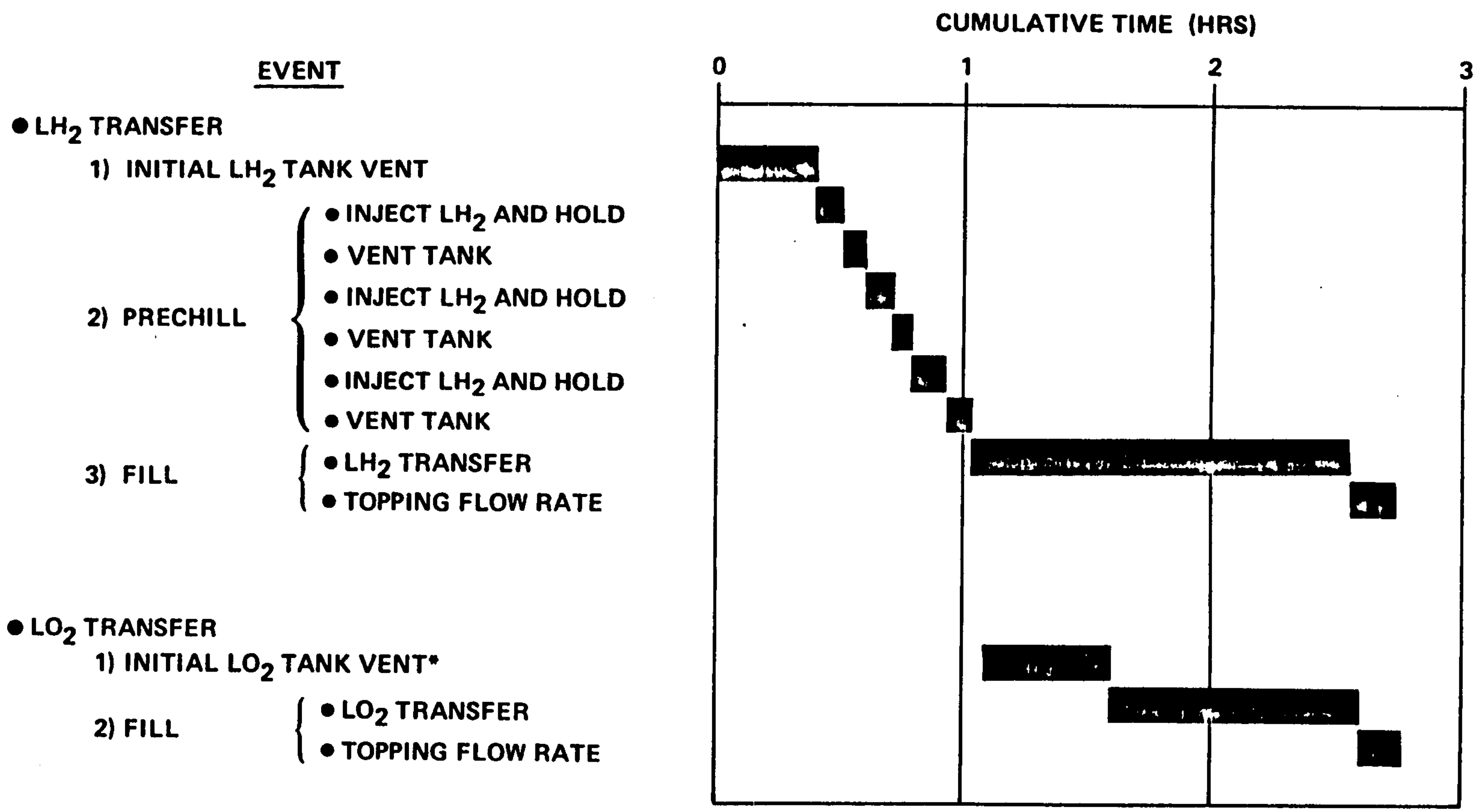
√ CONCLUSIONS

EP6567

# POTV PROPELLANT TRANSFER TIMELINE

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NOTES:

- TWO OR MORE ADDITIONAL VENT CYCLES REQUIRED IF HELIUM PRESENT
- TIMELINE IS FOR REFUELING TO 50% LEVEL

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**PRE–CHILL PREPARATIONS**

- DILUTION OF HELIUM RESIDUALS PRIOR TO REFUELING REQUIRED TO PREVENT:
  - EXCESSIVE PRESSURES AT END OF FILL
  - INACCURATE KNOWLEDGE OF PROPELLANT VAPOR PRESSURES
  - START BASKET HELIUM ENTRAPMENT
  - INACCURATE THERMODYNAMIC MASS GAUGING
- APPROXIMATE DILUTION LEVELS REQUIRED (POTV)
  - $LH_2 \leq$ .9 KG (2 LBS)
  - $LO_2 \leq$ .09 KG (.2 LBS)

  } FURTHER DILUTION REQUIRED IF THERMODYNAMIC MASS GAUGING UTILIZED
- PROCEDURAL/TECHNOLOGY CONCERNS
  - DURATION OF VENT/HOLD CYCLES
  - KNOWLEDGE OF HELIUM RESIDUAL MAGNITUDE

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**TRANSFER LINE/TANK CHILLDOWN:**

- REQUIREMENT: REDUCE TRANSFER LINE/TANK WALL TEMPERATURES SUFFICIENTLY TO PREVENT EXCESSIVE LINE PRESSURE/FLOW SURGES AND TO ENABLE A NON–VENTED TANK FILL
- PROCEDURAL/TECHNOLOGY CONCERNS:
  - TANK CHARGE/HOLD/VENT CYCLE DEFINITION
    - SEMI–EMPIRICAL MODELING LACKS EXPERIMENTAL DATA
    - LACK OF HARDWARE EXPERIENCE
    - WALL CHILLDOWN CRITERION: CURRENT RANGE = 95°K TO 200°K (170°R TO 360°R)
    - CHARGE MASS/FLOWRATE SELECTION: CURRENT $LH_2$ RANGE = 20 TO 70 KG (40 TO 155 LB) @ .5 TO 1.5 KG/SEC (1 TO 3 LB/SEC)
  - LACK OF TRANSFER LINE CHILLDOWN EXPERIENCE – PREVENTION OF EXCESSIVE SURGES AND LINE LOADS
  - INSTRUMENTATION TO MONITOR CHILLDOWN PROCESS

LP6597

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## TANK FILL

- REQUIREMENT: $LH_2$ & $LO_2$ TANK FILL WITHOUT VENTING
- PROCEDURAL/TECHNOLOGY CONCERNS:
  - ASSURANCE OF ADEQUATE CIRCULATION TO MAINTAIN NEAR–THERMAL EQUILIBRIUM, i.e., LOW PRESSURES
    - GOOD MIXING/HEAT EXCHANGE BETWEEN ULLAGE/LIQUID REQUIRED
    - EXISTING SEMI–EMPIRICAL MODELS LACK EXPERIMENTAL DATA
    - LACK OF IN–FLIGHT HARDWARE EXPERIENCE
    - MECHANICAL MIXER PROBABLY REQUIRED
  - LACK OF ZERO–G MASS GAUGING DEVICE
  - SPECIAL FILL PROVISIONS FOR START BASKET
    - BLEED LINE FOR DIRECT FILL OF BASKET
    - ACTIVE CIRCULATION TO ASSURE ENTRAPPED VAPOR COLLAPSE
  - SUPPLY TANK VAPOR PRESSURE $\leqslant$ 2.2 $kN/M^2$ (15 PSIA), NO HELIUM PASSAGE ALLOWABLE
  - PREVENTION OF EXCESSIVE TRANSFER LINE LOADS AT $\dot{m}$ = 1–1.5 KG/SEC (2–3 LB/SEC)

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