NASA JSC
U.S. Spacesuit Knowledge Capture Series

"U.S. SPACESUIT DEVELOPMENT AND QUALIFICATION" FOR PROJECT MERCURY

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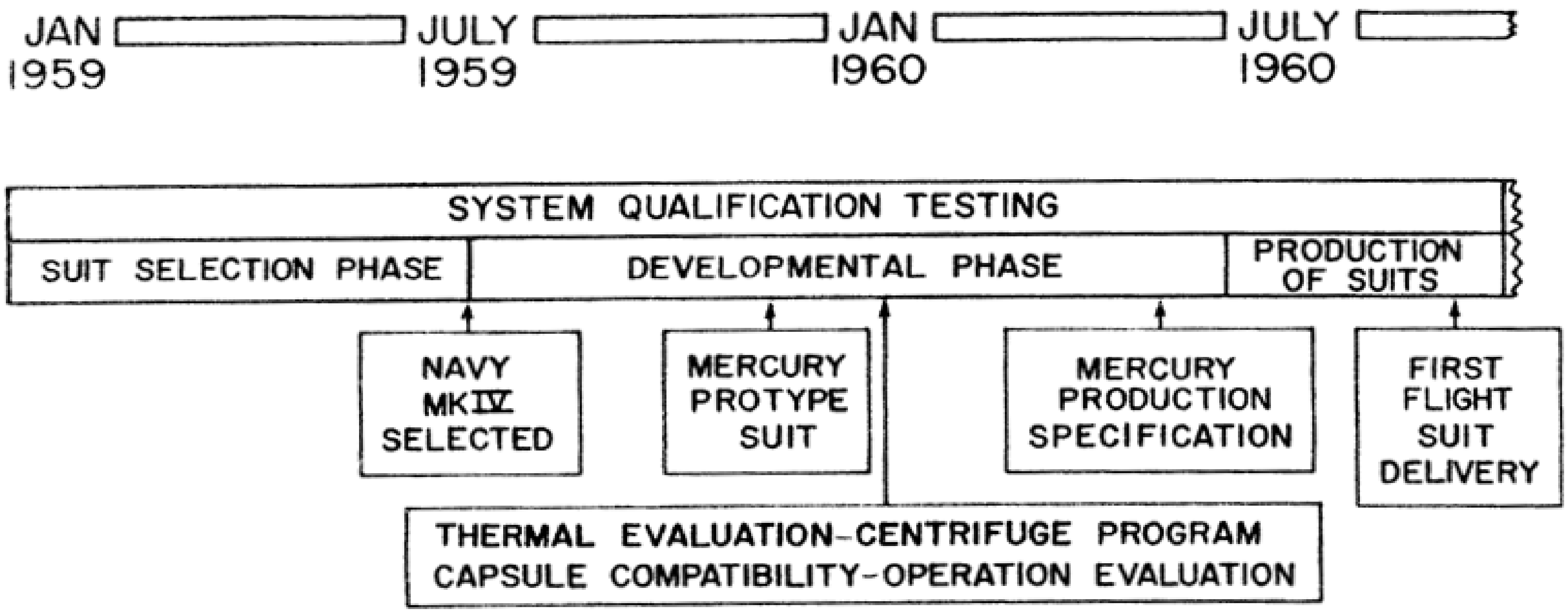
MERCURY FULL PRESSURE SUIT DEVELOPMENT AND QUALIFICATION TESTING PROGRAM*



*From Presentation at Aerospace Medical Association meeting
by SC White, RS Johnson, and FH Samonski Jr. -1962

SYSTEM QUALIFICATION TESTING
SUIT SELECTION PHASE

First Suit Conference – January 29,1959

- Attended by 40 high-altitude suit experts
- Recommendation established to conduct extensive suit evaluation program:
  David Clark, BF Goodrich, International Latex to provide suits
- NASA requested suit evaluations be completed mid-July by:
  USAF Aero Medical Laboratory
  NAVY Air Crew Equipment Laboratory

Second Suit Conference – July 15, 1959

- David Clark and BF Goodrich suits ranked highest by USAF and Navy
- NASA decided to perform concurrent development and evaluation with both David Clark and BF Goodrich
- Development to include various combinations of suits and ventilation systems
- Concern was capsule and ECS integration requirements

SYSTEM QUALIFICATION TESTING
SUIT SELECTION PHASE

- **EVALUATION TESTING:**
  - **WPAFB Aeromedical Laboratory**
    - 24-hour manned chamber tests to check mobility and fitting
    - 180 deg F manned temperature exposure for 2 hrs
    - 8 g's manned centrifuge exposure
    - Sound reduction features
  - **McDonnell Aircraft Corporation**
    - Capsule compatibility

- **NASA SELECTION FACTORS INCLUDED:**
  - Mobility
  - Compactness
  - Reliability
  - Resistance to temperature
  - Pressure Integrity
  - Ease of donning and doffing

- **SUIT CONTRACT AWARDED TO B.F. GOODRICH ON JULY 22, 1959**

SYSTEM QUALIFICATION TESTING
SUIT SELECTION PHASE

USAF and NAVY COMPETITIVE SUITS TESTING – 1959

NASA SELECTED SUIT

Modified Navy Mark IV

B. F. Goodrich Co.

SUITS NOT SELECTED

Modified USAF X-15 MC-2

David Clark Co.

SPD-117 Prototype

International Latex Co.

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SUIT SYSTEM CONCEPT DIFFERENCES

NAVY Mark IV Pressure Suit used a two gas system.

- Breathing oxygen supplied to the oral nasal cavity by a helmet-mounted demand oxygen regulator
- Oral nasal cavity separated from larger suit cavity by a face seal inside helmet
- Exhaled breathing gas exhausted by a check valve into main suit cavity
- Main suit cavity pressurized by compressed air from aircraft cabin pressurization system
- Exhaust breathing gas, ventilating and pressurizing air exits through seat-pack mounted pressure controller into cabin

Mercury Pressure Suit used a one gas-closed, recirculating pressurizing, ventilating, and breathing system.

- Oral-nasal area not separated from remaining suit cavity
- A nearly pure oxygen atmosphere supplied to the suit for pressurizing, ventilating, and breathing from cabin ECS
- Exhaust gases recirculated through cabin ECS where they are reconditioned and reused
- The cabin ECS oxygen supply limited so outboard suit leakage is held to a minimum
- Pressure drop through suit system held to a minimum to avoid excessive cabin ECS system power loss

SYSTEM QUALIFICATION TESTING
DEVELOPMENT PHASE

- **U.S. Navy Contract Award To B.F. Goodrich – July 22, 1959**

- **21 suits plus 2 spare parts kits:**
  4 operational research suits (XN1, XN2, XN3, XN4) made for:
    - W Schirra, and Dr. Douglas (flight surgeon),
      Gilbert North (McDonnell Douglas), Warren North (NASA Hq)

  9 suits for engineers and astronauts to be specified

  8 final configuration suits
    - one pre-production suit for qualification testing
    - seven production suits for flight

- **Estimated Cost:**
  $75,000.00

SYSTEM QUALIFICATION TESTING
DEVELOPMENT PHASE

- **ADDITIONAL DEVELOPMENT TESTS** – Late 1959
  - Thermal evaluation at USN ACEL
    - Simulation suited in re-entry heat chamber at 280 Deg for 5 min
  - Capsule compatibility
    - Conducted at McDonnell Aircraft Company, St. Louis. MO
  - Operational evaluation
    - Conducted at Space Task Group, Langley Field, VA

- **SUIT DESIGN ISSUES IDENTIFIED**
  - Fabric stretching
  - User discomfort
  - Poor gas circulation

SYSTEM QUALIFICATION TESTING
DEVELOPMENT PHASE

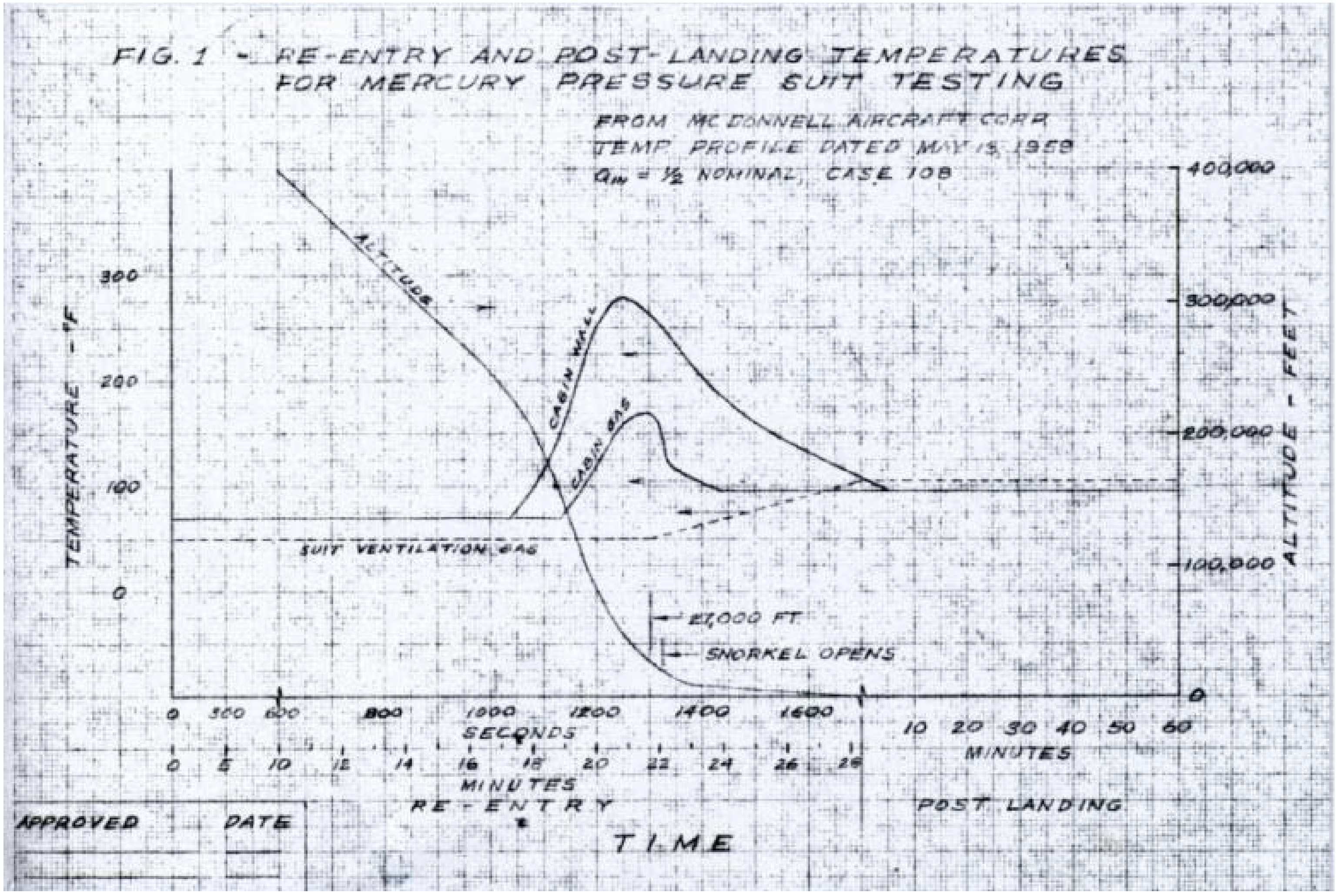
Robert R. Gilruth letter to chief, U.S. Navy Bureau of Weapons – Jan 1960

- NASA provided heating data from Big Joe re-entry test and ECS testing for suit thermal performance study.
  - Identified development programs to be pursued:
    - Solve suit materials problems to prevent stretching after heat testing and wear
    - Finalize suit heat protection and ventilation configuration
    - Improve suit compatibility with Mercury capsule
    - Complete exhaustive qualification testing of all suit components including subjecting all materials to orbital vacuum conditions
    - Develop an in-suit urine collection system that will work in zero gravity
    - Continue development of suit ventilation system with emphasis on improving torso ventilation

- Enclosures provided with letter:
  1. Mercury Pressure Suit Heat Test Requirements
  2. Development Schedule Requirements

SYSTEM QUALIFICATION TESTING
DEVELOPMENT PHASE

Enclosure 1 - Mercury Pressure Suit Heat Test Requirements



SYSTEM QUALIFICATION TESTING
DEVELOPMENT PHASE

Enclosure 2 – Mercury Suit Development Schedule

Completion of tests described in enclosure (1)	February 1, 1960
Delivery of suits No. 11-13 of Mercury pressure suit contract (suits to be fitted for W. S. Augerson, W. M. Schirra, and L. N. McMillion of NASA Space Task Group)	March 5, 1960
Completion of hardware qualifications	March 15, 1960
Completion of Augerson, McMillion and Schirra evaluations of ventilation, heat protection, comfort and mobility	March 15, 1960
Delivery of pre-production suit (No. 14 under Mercury suit contract)	March 30, 1960
Commence production of Astronaut suits (Nos. 15-21 under Mercury suit contract)	April 15, 1960

SYSTEM QUALIFICATION TESTING
DEVELOPMENT PHASE

NASA Design Conference – May 1960

- **Additional Mark IV Suit design changes**
  - Segmented shoulders with diagonal pleat panels at rear
  - Straps added to prevent shoulder rise and under arm cutting
  - Elbow and leg joints to assume bent position when suit pressurized
  - Extra sponge rubber thermal insulation layer deleted.
  - Curved-fingered gloves with 1 straight finger
  - Extra threads woven into gloves outer layer to provide roughened texture for easier manipulation of display push buttons and flick switches.
  - Custom-sized tailoring using body molds of astronauts

- **Additional Cost:**
  - $100,000.00

SYSTEM QUALIFICATION TESTING
DEVELOPMENT PHASE

Mercury Suit Specification - 1960

- **Suit System:**
  - Operational temperature Range: -65 to +180 deg F
  - Operational suit Pressure - 0.15 and 5.0 psig
  - Leakage: 200 cc/min max
  - Pressure drop: 4.5 in water at 10.5 cfm vent flow
  - Custom-sized at Factory
  - Weight: 30 lbs max
  - Compatible with capsule ECS and controls and displays

- **Suit Components:**
  - Helmet
  - Torso
  - Gloves
  - Ventilation under garment

SYSTEM QUALIFICATION TESTING
DEVELOPMENT PHASE

MERCURY PROTOTYPE SUIT – Late 1959

SYSTEM QUALIFICATION TESTING
DEVELOPMENT PHASE

MERCURY PRODUCTION SUIT SPECIFICATION – 1960

- **Helmet:**
  - Retractable clear Plexiglas visor with open position lock
  - Visor closed position sealed and locked by inflatable bladder seal
  - Visor bladder seal internal pressure 35 to 95 psi
  - Bladder inflated by auxiliary oxygen source – deflated by an on-off button
  - Visor bladder seal capable of 100 actuations – by left hand
  - Visor defogging accomplished by ventilation flow
  - Visual field: 95 deg either side of center line
    45 deg above and 75 deg below visual center line
  - Detachable and quickly removal pressure sealing neck ring
  - Conformal removable and non-crushable shock absorbing padding
  - 1 inch ID ventilation outlet located on right side – connection operable by one hand
  - Max comfort for 30-hour wear
  - Min effort for full head nodding at 5 psi
  - Tie down to torso to prevent helmet lifting while pressurized
  - Absorbent sweat band to protect eyes from perspiration

SYSTEM QUALIFICATION TESTING DEVELOPMENT PHASE

MERCURY PRODUCTION SUIT SPECIFICATION – 1960

- **Helmet Communications:**
  - A-1C/10 Interphone system
  - Smallest microphones and earphones available – capsule compatible
  - 2 microphones, each wired to a separate circuit
  - Each earphone on individual circuit
  - Each ear cup provide min of 20 db sound attenuation

- **Torso:**
  - Extends from neck ring down to encompass feet and extend to lower 1/3 of forearm
  - Circumferential sizing lacing and adjustment straps kept to minimum
  - No excess bulk; foot socks fixed to leg with multiple sizes
  - Provision to prevent inboard water leakage when helmet removed
  - Joints and disconnects to permit freedom of mobility – all conditions
  - Joints and disconnects to prevent external gas leakage and internal water leakage
  - 1 inch ID Hose disconnect on left side attachable and detachable with one hand
  - Entrance closure allows minimum effort to don and doff suit
  - Pressure gage on left thigh, color-coded 3.0 to 5.5 psig range, 23 psia compatible
  - 16 terminal bio-patch with no sharp or thick areas on backside

SYSTEM QUALIFICATION TESTING
DEVELOPMENT PHASE

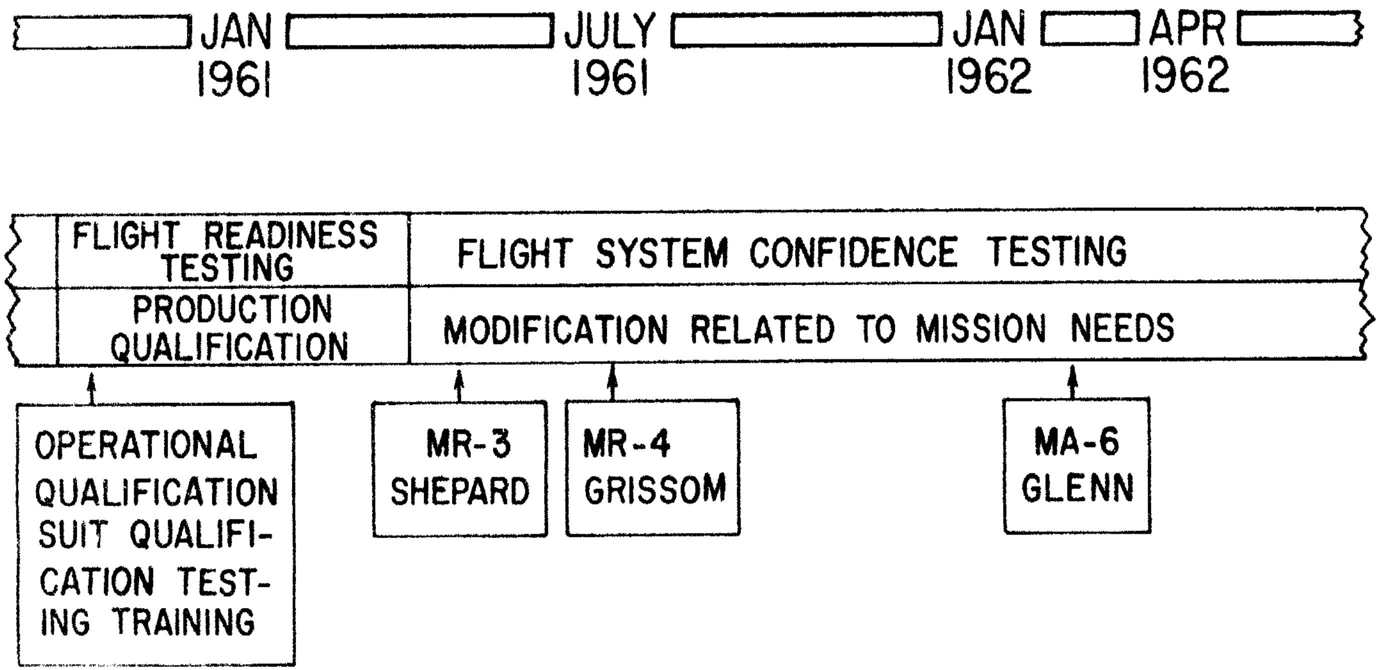
MERCURY PRODUCTION SUIT SPECIFICATION – 1960

- **Gloves:**
  - Extend from lower 1/3 of forearm to fingertips
  - Joined at torso arms by disconnect
  - Gas retention bladder and restraint member
  - Palm restraint provided – to prevent ballooning
  - Wrist strap provided – to facilitate wrist bending
  - Outer friction surface on inside of fingers to provide tactility

- **Boots:**
  - Provide wear protection over torso foot section
  - Soles to have friction surface

- **Ventilation System Under Garment**
  - Provide thermal comfort and safety for time-temperature requirements of capsule
  - No cold spots on body with gas inlet of 45 deg F at10 cfm and 5 psi suit pressure
  - No binding or pressure points after suit donning
  - 3 garments provided with each suit

MERCURY FULL PRESSURE SUIT DEVELOPMENT AND QUALIFICATION TESTING PROGRAM*



*****From Presentation at Aerospace Medical Association meeting by SC White, RS Johnson, and FH Samonski Jr. -1962

FLIGHT READINESS TESTING

Production Suit Qualification

- **Pre-production Acceptance Tests** - Performed in order listed **on one suit:**

- Leakage: Not to exceed 200 scc/min at 5.0 psig suit pressure

- Environmental Stress:
- 180 deg F ambient at 7.5 psig suit pressure with vent inlet air flow of 3.25 cfm at 70 deg for 30 min duration
- Continue 180 deg F ambient at 5.0 psig suit pressure with no vent inlet air flow for an additional 30 min duration
  - Leakage not to exceed 200 scc/min
- Continue at room temperature at 5.0 psi suit pressure with vent inlet air flow at 3.25 cfm at 70 deg for an additional 24 hrs duration
  - No structural or other defects
  - Leakage not to exceed 200 scc/min at 5.0 psi suit pressure

- Proof Environmental:
- 180 deg F at 5.0 psig with vent flow of 3.25 cfm for 30 min
- Helmet only at 7.5 psig – same other conditions
  - Visual for defects, damage, etc.
  - Leakage less 250 scc min at 5.0psig - at room temperature

FLIGHT READINESS TESTING

Production Suit Qualification

- **<u>Pre-production Acceptance Tests</u>** - (Cont)

  - Suit Endurance after Exposure:
  - 24 hrs at 100 deg F (plus/minus 5 deg) at 95 RH
  - 4 hrs at -40 deg F (plus/minus 5 deg)
  - 20 hrs at 160 deg F and dry
  - Above conditions repeated for 3 cycles
  - Pressurize from 0 to 5 psi in 3 sec for 500 cycles
  - Examine for defects
  - Leakage less than 250 cc/min at room temperature at 5.0 psig

  - Closures Endurance:
  - 500 cycles (open and close) for all external gas leakage and internal water leakage closures
  - Leakage less than 250 cc/min at room temperature at 5.0 psig

FLIGHT READINESS TESTING

Production Suit Qualification

- **<u>Pre-production Acceptance Tests</u>** – (cont)

  - **Visor inflation hose**
    - Withstand hose tension load of 75 lbs. – fittings end to end
    - 150 psi internal pressure – no porosity when submerged in water

  - **Visor seal cycling**
    - 1000 cycles with no leakage with actuation button in off position
    - No evidence of visor seal porosity

  - **Pressure drop at sea level**
    - Less than 4 in. water at vent flow of 3.25 cfm STP

  - **Pressure Drop at Altitude**
    - Less than 5 in. of water while suited at 27,000 ft and flow of 10 cfm

FLIGHT READINESS TESTING

Production Suit Qualification

- **<u>Pre-production Acceptance Tests</u>** – (Cont)

  - **Visor Defogging:**
    - Correctly fitted suited subject breathing oxygen, visor in down position, at 60 deg F for 60 min with oxygen flow at 3.5 acfm saturated at 45 deg F
    - Anti-fog compound may be applied
    - No visibility impairment

  - **Explosive Decompression:**
    - Decompress from 8,000 to 27,500 ft in 0.2 sec with vent airflow of 100 LMP STP.
    - Examine for damage
    - Leakage less than 200 scc/min

  - **Visual field:**
    - Minimum of 95 deg either side of center line and through a vertical included angle of 45 deg above and 75 deg below a plane level with the line of sight
    - Head fixed in normal fixed position

FLIGHT READINESS TESTING

Production Suit Qualification

- **<u>Pre-production Acceptance Tests</u>** - (Cont)

- Suit Pressure Gage:

- Accelerated to 25 g's in both directions along all 3 axis.
- Drop-tested to impacts of 45 g's in both directions along 3 axis with onset rate of impacts to exceed 50,000 g/sec.
- Recalibrate to verify gage limits are within +/- 0.1 psi.
- Cycle pressure from 0 to 8 psig 15 times
- Recalibrate to verify gage limits +/- 0.1 psi.
- Install on suit and subject to low pressure chamber between pressures of 3.0 to 5.5 psia. Deviation less than 0.1 psi.
- Decompress suit to 27,000 to 50,000 ft within 150 milliseconds.
- Recalibrate to verify gage limits are within +/- 0.1 psi.

- Suit Pressure Gage Calibration:

- Calibrate against mercury column at 3.0, 3.5, 4.0, 5.0, and 5.5 psia with deviation less than +/- 0.1 psi

FLIGHT READINESS TESTING

Production Suit Qualification

- **<u>Pre-production Acceptance Tests</u>** - (Cont)

- Helmet engagement test:

- Helmet-locking device engaged and disengaged 100 cycles.
- Examine for defects.

- Helmet Static Loading:

- Apply 300 lbs. to helmet apex with 8 lb. spherical steel weight.
- Examine for cracks, structural failure, or visible distortion.

- Helmet Bottoming:

- With padding installed, apply 8 lb. spherical steel weight free dropped from height of 6 ft
- Examine for serious evidence of uneven distribution of loads between padding and dummy head

- Helmet Sound Attenuation:

- Conduct at both 0.15 and 5 psig per CHABA Standard Method.

FLIGHT READINESS TESTING

Production Suit Qualification

- **<u>Pre-production Acceptance Tests</u>** - (Cont)

  - **Piercing Resistance:**
    - Helmet resist piercing by impact by 16 oz. steel plumb-bob pointed 60 deg dropped from height of 4 ft
    - Points of impact one in each of six 60-deg sectors of helmet
    - No more than 0.125 protrusion at any impact point

  - **Final Leakage:**
    - Shall not exceed 250 cc/min at room temperature at 5.0 psig.

FLIGHT READINESS TESTING

Production Flight Suit Acceptance

- **<u>Acceptance Tests</u>** (Performed in order listed **<u>on each</u>** suit)

  - Helmet Static Loading
  - 300 lbs applied at shell apex with 8-lb spherical steel weight
  - Examine for visual defects, damage, etc.

  - Pressure gage calibration
  - 3.0 to 5.5 psia at 0.5 psi increments – deviation less than +/- 0.1 psi

  - Proof Environmental
  - 180 deg F at 5.0 psig with vent flow of 3.25 cfm for 30 min
  - Helmet only at 7.5 psig – other conditions same as above
  - Examine for visual defects, damage, etc.
  - Leakage less 250 scc min at 5.0 psig - at room temperature

  - **Pressure drop at sea level**
  - Less than 4 in. water at vent flow of 3.25 cfm STP

FLIGHT READINESS TESTING

Production Flight Suit Acceptance

- **<u>Acceptance Tests -</u>** (cont.)

- Visor inflation hose test

- Withstand hose tension load of 75 lbs. – fittings loaded end to end
- 150 psi internal pressure – no porosity when submerged in water

- Visor seal cycling test

-100 cycles with no leakage with actuation button in off position

- Helmet engagement test

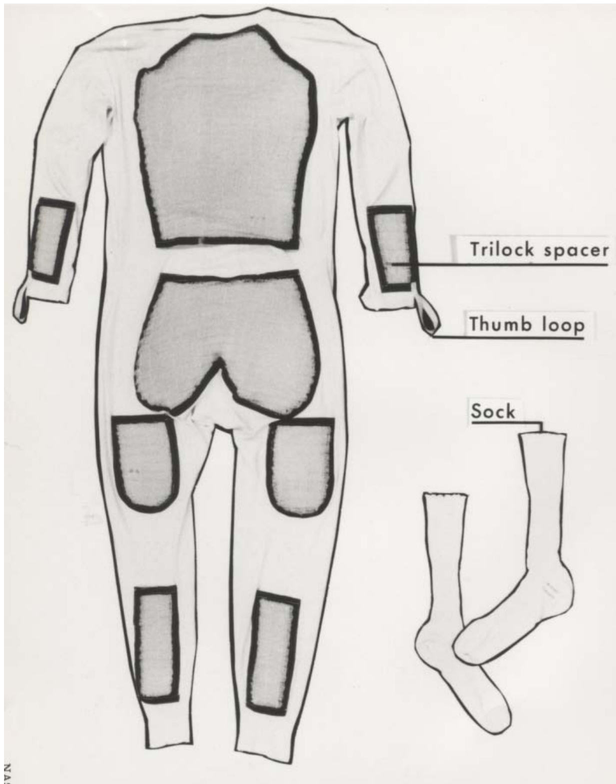
- 100 cycles engage/disengage – no locking mechanism defects

- Final leakage test

- Less than 250 cc/min at 5.0 psig

- Communication system - operable when transmitting and receiving

MR-3 FLIGHT CONFIGURATION BASELINE



Modifications Related To Mission Needs

- **MR-3 Al Shepard – May 5, 1961**
  15 min, 28 sec - suborbital
  - Baseline suit configuration

- **MR-4 Gus Grissom – July 21, 1961**
  15 min, 37 sec – suborbital
  In-water Suit survival
  - Configuration same as **MR-3** plus:
  - Replace wrist zipper closure disconnects with self-don bearing
  - Add parabolic mirror on chest
  - Remove “widows” peak from helmet

Modifications Related To Mission Needs

- **MA-6 John Glenn Flight – February 20, 1962**
  4 hrs, 55 min 23 sec – first orbital flight
  - Configuration same as **MR-4** plus:
  - Replace glove wrist buckles with smaller size
  - Remove torso vent duct disconnect
  - Install finger tip lights and battery on both gloves
  - Install self-closing vent inlet closure disconnect
  - Replace Roanwell with Electrovoice microphones
  - Added 0.15 psig leakage tests - wrist bearing seal installed backwards - caused excessive ECS leakage
  - Added life vest on parabolic mirror

- **MA-7 Scott Carpenter Flight – May 24, 1962**
  4 hrs, 56 min, 5 sec - second orbital flight
  - Configuration same as for **MA-6** plus:
  - Replace molded rubber glove bladders with Estane dipped bladders
  - Add red coloring on left glove finger tip lights

Modifications Related To Mission Needs

- **MA-8 Walter Schirra Flight – October 23,1962**
  9 hrs, 13 min, 11 sec – third orbital flight
  - Configuration same as **MA-7** plus:
  - Add strain relief at top of pressure sealing closure
  - Replace wrist disconnect lock AL material with SS
  - Replace Elecrovoice microphones with Plantronics microphone

- **MA-9 Gordon Cooper Flight – May 15/16, 1963**
  First one Day Mercury Program Flight
  34 hrs, 19 min, 49 sec – last orbital flight
  - Same as **MA-9** plus:
  - Replace Plantronics microphones with Plantronics noise canceling microphones
  - Replace pneumatic visor seal with mechanical visor seal helmet
  - Replace separately donned boots with integral boots

Modifications Related To Mission Needs

- **Changes Implemented as Necessary for all Flights:**
  - Fabricated, installed, and relocated accessory pockets; and attachment loops, snaps, and Velcro fasteners.

MERCURY PRESSURE SUIT

SIGNIFICANT LESSONS LEARNED

- **SUIT ASSEMBLY**
  - New requirement identified to add pre-flight low pressure leakage testing

- **TORSO**
  - Excessive bladder leakage
    - Repetitive re-rolling and re-bonding of adhesive bonded seams
    - Frequent leakage testing necessary
  - Frequent factory replacement of pressure sealing slide closure
    - Reinforcement gussets added at closure ends
  - Excessive low-pressure leakage during on-pad capsule ECS test
    - Wrist-bearing seal installed backwards
  - Flotation necessary for post landing water survival
    - Added on-suit worn life preserver and deployable neck dam

MERCURY PRESSURE SUIT
SIGNIFICANT LESSONS LEARNED

- **HELMET**
  - Exhaust oxygen location caused eye irritation and distracting noise
  - Visor seal inflation bottle leakage
    - Solved by MA-9 mechanical visor closure
  - Visor anti-fog solution needs to be applied just before flight
- **GLOVES**
  - Long term wear comfort and limited hands and fingers mobility/dexterity need improvement

Advanced Suit Technology Development
Contract NAS 9-252 with B.F. Goodrich
Awarded April 1962

- **One Day Mercury Program Application**
  - MA-10 to MA-13 Missions
  - Approved October 23, 1961
- **Suit Design Objectives:**

  - Improve
  - Unpressurized suit comfort – removable arm and leg components
  - Suit ventilation – relocate exhaust fitting to torso
  - Suit mobility – repatterned joints; bearings; bellows; “slip net” fabric
  - Operational reliability – relocate pressure sealing closure

  - Incorporate
  - Mechanical visor seal closure mechanism
  - Electrically heated helmet visor
  - Light attenuation visor

- **NASA Administrator cancelled One Day Mercury Program June 12, 1963.**
  - Continuation “to risky based on MA-9 systems failures”
  - Gemini Project underway needed additional resources

- **Technology development re-directed to support Project Gemini suit development**

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