



# *Metrology Services*

**NORTHROP  
GRUMMAN**

## ***Metrology Services***

2425 Manhattan Beach Blvd.  
Bldg. 120 – Door # 10  
Redondo Beach, CA 90278

Tel: 310-813-0000

Fax: 310-814-8797

E-mail: [metrology.services@ngc.com](mailto:metrology.services@ngc.com)

[www.northropgrumman.com/aerospaceTestServices](http://www.northropgrumman.com/aerospaceTestServices)



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Northrop Grumman provides advanced technology products and services for the automotive, space and defense and information technology markets worldwide.

Located in Redondo Beach, California, Northrop Grumman's Aerospace Systems (NGAS) produces, integrates and tests electronic space payloads; produces advanced microelectronics integrated circuits and modules for telecommunications; develops advanced space instruments and builds commercial and military lasers.

The 24,000 square feet Metrology Standards Lab and Test Engineering Asset Management (EAM) have supported internal technology for more than 50 years, developing an extensive range of capabilities.

Metrology Services were first offered outside the company in 1988 to extend internal capabilities as a resource to companies requiring additional calibration support. On-site calibration is available upon request.

## ***Services & Specialized Consulting***

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- **Calibration & Repair**
  - **Special Measurements:**
    - RF/millimeter wave development, phase noise evaluations, fiber optics, laser power
  - **Metrology Engineering Consulting:**
    - Characterization and Validation
    - Phase Noise
    - Millimeter Wave Measurements
    - Software development (HP VEE, Visual Basic)
  - **Customized Training Programs:**
    - Metrology Fundamentals, Calibration & Repair, HP VEE
  - **Measurement and Test Development:**
    - Methodologies, System Design, Automation and Procedures
    - **Calibration, Procedures and Systems for AS9100 / ISO 900X**
      - Metrology Training for Calibration Technicians
        - Uncertainty, Environmental and Interval Analysis, Measurement Technique, Dimensional, Physical, DC/Low Frequency and RF/Microwave Develop calibration and recall system
        - Review and generate calibration procedures, standard operating procedures and command media.
        -
  - **Managing Test Equipment**
    - Consulting offered to help you attain superior financial returns on your investment in technology assets
      - Assessment of processes from Acquisitions thru Disposal, with follow-on Strategies and Training of key personnel
      - Optional Software tools
-

## TYPICAL INSTRUMENTATION SERVICED

|   |   |   |
|---|---|---|
| <p><b>ADAPTER</b><br/>COAXIAL TO COAXIAL<br/>WAVEGUIDE TO COAXIAL<br/>WAVEGUIDE TO WAVEGUIDE</p> <p><b>AIR LINE</b><br/>COAXIAL</p> <p><b>AMPLIFIER</b><br/>CHARGE<br/>DATA<br/>GENERAL PURPOSE<br/>LOCK-IN<br/>POWER<br/>PULSE</p> <p><b>ANALYZER</b><br/>GAS<br/>MOISTURE<br/>OXYGEN</p> <p><b>ANALYZER (ELECTRONIC)</b><br/>DATACOMM, DIGITAL<br/>DISTORTION<br/>NETWORK<br/>SPECTRUM<br/>WAVE</p> <p><b>ANEMOMETER</b><br/>THERMAL<br/>VANE</p> <p><b>ATTENUATOR</b><br/>FIXED<br/>VARIABLE</p> <p><b>BALANCE</b><br/>ANALYTICAL<br/>LABORATORY<br/>TOP LOADING</p> <p><b>BATH (CONSTANT TEMP)</b><br/>LIQUID</p> <p><b>BEND</b><br/>WAVEGUIDE</p> <p><b>BIAS NETWORK</b><br/>MICROWAVE</p> <p><b>BLOCK</b><br/>GAGE, ANGLE SET<br/>GAGE, SET<br/>MAGNETIC<br/>VEE</p> <p><b>BRIDGE</b><br/>CAPACITANCE<br/>CONDUCTIVITY<br/>IMPEDANCE<br/>INDUCTANCE</p> | <p><b>BRIDGE</b><br/>RESISTANCE<br/>TEMPERATURE, OHMS READING</p> <p><b>CALIBRATOR</b><br/>FLOW, GAS<br/>PRESSURE, DEAD WEIGHT</p> <p><b>CALIBRATOR (ELECTRONIC)</b><br/>ATTENUATOR<br/>AUDIO/MICROPHONE<br/>OHMS<br/>POWER METER</p> <p><b>CALIBRATOR (VOLTS/AMPS)</b><br/>AC CURRENT<br/>AC VOLTAGE<br/>DC CURRENT<br/>DC VOLTAGE</p> <p><b>CALORIMETER</b><br/>LASER</p> <p><b>CAPACITOR</b><br/>DECADE<br/>FIXED<br/>VARIABLE</p> <p><b>CHAMBER</b><br/>FREEZER<br/>FURNACE<br/>OVEN<br/>TEMPERATURE<br/>TEMPERATURE/HUMIDITY</p> <p><b>CONTROLLER (ELECTRONIC)</b><br/>TEMPERATURE</p> <p><b>CONVERTER (SIGNAL)</b><br/>AC/DC TO LOGARITHMIC<br/>ANALOG TO DIGITAL<br/>DIGITAL TO ANALOG<br/>FREQUENCY TO VOLTAGE<br/>VOLTAGE-TO-FREQUENCY<br/>VOLTAGE, THERMAL</p> <p><b>COUNTER (ELECTRONIC)</b><br/>AUTOMATIC COMPUTING<br/>FREQUENCY<br/>UNIVERSAL<br/>PRESET<br/>REVERSIBLE<br/>TIME INTERVAL<br/>TOTALIZER</p> <p><b>COUPLER</b><br/>DIRECTIONAL<br/>HYBRID</p> <p><b>DATA ACQUISITION SYSTEM</b><br/>DIGITAL/ANALOG</p> | <p><b>DELAY LINE</b><br/>FIXED<br/>VARIABLE</p> <p><b>DENSITOMETER</b><br/>OPTICAL</p> <p><b>DETECTOR</b><br/>LEAK<br/>MICROWAVE</p> <p><b>DISPLAY</b><br/>DIGITAL, MODULAR</p> <p><b>DIVIDER</b><br/>POWER, MICROWAVE</p> <p><b>DIVIDER, DC/AC</b><br/>VOLTAGE</p> <p><b>DIVIDER, AC VOLTAGE</b><br/>RATIO TRANSFORMER</p> <p><b>DOSIMETER</b><br/>NUCLEAR</p> <p><b>FILTER</b><br/>BAND PASS, FIXED<br/>BAND PASS, VARIABLE<br/>BAND REJECT, FIXED<br/>BAND REJECT, VARIABLE<br/>HIGH PASS<br/>LOW PASS<br/>MULTIFUNCTION<br/>NOTCH</p> <p><b>FLOW MEASUREMENT</b><br/>FLOWMETER, GAS</p> <p><b>GAGE (DIMENSIONAL)</b><br/>HEIGHT<br/>CYLINDRICAL PLUG</p> <p><b>GAGE (ELECTRONIC)</b><br/>VACUUM</p> <p><b>GAGE (INDICATOR TYPE)</b><br/>FORCE<br/>PRESSURE<br/>PRESSURE, ABSOLUTE<br/>PRESSURE, COMPOUND<br/>PRESSURE, DIFFERENTIAL<br/>PRESSURE, GAS<br/>PRESSURE, LIQUID<br/>VACUUM</p> <p><b>GAGE/CONTROLLER (ELEC)</b><br/>VACUUM, ANALOG<br/>VACUUM, DIGITAL</p> |
|---|---|---|

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|---|--|---|
| <p><b>GENERATOR (ELECTRONIC)</b><br/>           DELAY<br/>           FREQUENCY STANDARD<br/>           FREQUENCY SYNTHESIZER<br/>           FUNCTION<br/>           TIME MARK<br/>           NOISE<br/>           NOISE SOURCE<br/>           OSCILLATOR<br/>           POWER PULSE<br/>           POWER SIGNAL<br/>           PULSE<br/>           RATE<br/>           SIGNAL<br/>           SQUARE WAVE<br/>           SWEEP<br/>           WORD/DATA</p> <p><b>HYGROMETER</b><br/>           DEW POINT<br/>           DIRECT READING</p> <p><b>INDICATOR (ELECTRONIC)</b><br/>           LINEAR<br/>           DISPLACEMENT<br/>           PRESSURE, ANALOG<br/>           STRAIN<br/>           TRANSDUCER, UNIVERSAL</p> <p><b>INDUCTOR</b><br/>           DECADE<br/>           FIXED</p> <p><b>ISOLATOR</b><br/>           MICROWAVE</p> <p><b>LEAK</b><br/>           FIXED RATE</p> <p><b>LOAD (ELECTRONIC)</b><br/>           ACTIVE</p> <p><b>MANOMETER</b><br/>           ANALOG<br/>           DIGITAL<br/>           FLUID</p> <p><b>MEASURING SYSTEM</b><br/>           COORDINATE</p> <p><b>METER</b><br/>           FIELD INTENSITY<br/>           FREQUENCY GAS, WET TEST<br/>           ILLUMINANCE/FOOT CANDLE<br/>           LASER POWER<br/>           MODULATION FM/AM<br/>           NOISE FIGURE<br/>           NULL</p> | <p><b>METER</b><br/>           PEAK MEMORY VOLTMETER<br/>           PH<br/>           PHASE<br/>           POWER<br/>           SOUND LEVEL<br/>           STANDING WAVE RATIO (SWR)</p> <p><b>METER (RCL)</b><br/>           CAPACITANCE<br/>           IMPEDANCE<br/>           IMPEDANCE, VECTOR<br/>           INDUCTANCE<br/>           Q</p> <p><b>METER (VOA)</b><br/>           AMMETER, AC<br/>           AMMETER, AC/DC<br/>           AMMETER, DC<br/>           ELECTROMETER<br/>           MULTIMETER<br/>           OHMMETER<br/>           VOLT, DIGITAL, PANEL DC<br/>           VOLTMETER, AC<br/>           VOLTMETER, AC/RF<br/>           VOLTMETER, DC<br/>           VOLTMETER, DIFFERENTIAL AC/DC<br/>           VOLTMETER, DIFFERENTIAL DC<br/>           VOLTMETER, DIGITAL AC/DC<br/>           VOLTMETER, DIGITAL DC<br/>           VOLTMETER, TRUE RMS<br/>           VOLTMETER, VECTOR</p> <p><b>MICROMETER</b><br/>           BORE/HOLE SET<br/>           DEPTH<br/>           INSIDE<br/>           OUTSIDE</p> <p><b>MICROPHONE</b></p> <p><b>MICROSCOPE</b><br/>           BINOCULAR<br/>           MEASURING<br/>           METALLOGRAPH<br/>           METALLURGICAL<br/>           STEREO</p> <p><b>MISMATCH</b><br/>           MICROWAVE</p> <p><b>MIXER (ELECTRONIC)</b><br/>           MICROWAVE</p> <p><b>MONITOR</b><br/>           RADIATION, NUCLEAR<br/>           PARTICLE COUNTER</p> <p><b>MULTIPLIER</b><br/>           FREQUENCY</p> | <p><b>OPTICAL</b><br/>           AUTOCOLLIMATOR<br/>           CATHETOMETER<br/>           CLINOMETER<br/>           COM PARATOR<br/>           FLAT</p> <p><b>OSCILLOSCOPE</b><br/>           DIGITAL STORAGE<br/>           DISPLAY UNIT<br/>           DISPLAY UNIT, STORAGE<br/>           DUAL BEAM<br/>           GENERAL PURPOSE<br/>           SAMPLING<br/>           STORAGE</p> <p><b>OSCILLOSCOPE ACCESSORY</b><br/>           CALIBRATOR, AMPLITUDE<br/>           UNINTERRUPTIBLE (UPS)<br/>           NORMALIZER<br/>           PLUG-IN, COUNTER<br/>           PLUG-IN, DIFFERENTIAL<br/>           PLUG-IN, DMM<br/>           PLUG-IN, DUAL TRACE<br/>           PLUG-IN, FOUR TRACE<br/>           PLUG-IN, LOGIC ANALYZER<br/>           PLUG-IN, SAMPLING<br/>           PLUG-IN, SAMPLING SWEEP<br/>           PLUG-IN, SAMPLING/TDR<br/>           PLUG-IN, SINGLE TRACE<br/>           PLUG-IN SPECTRUM ANALYZER<br/>           PLUG-IN, SWEPT FREQUENCY<br/>           PLUG-IN, TIME BASE<br/>           SAMPLING HEAD<br/>           TRIGGER COUNTDOWN</p> <p><b>PHASE SHIFTER</b><br/>           MICROWAVE</p> <p><b>PHOTOMETER</b><br/>           OPTICAL</p> <p><b>PLATE</b><br/>           ANGLE<br/>           SINE<br/>           SURFACE</p> <p><b>POTENTIOMETER</b><br/>           PRECISION<br/>           TEMPERATURE<br/>           DIRECT READING</p> <p><b>POWER</b><br/>           INVERTER</p> |
|---|--|---|

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|---|--|--|
| <p><b>POWER SUPPLY</b><br/>AC<br/>DC COMPUTER CONTROLLED<br/>DC CURRENT REGULATED<br/>DC GENERAL PURPOSE<br/>DC PRECISION<br/>KLYSTRON<br/>MODULAR<br/>PLATING<br/>PULSE, CURRENT<br/>REGULATOR, VOLTAGE, AC<br/>UNINTERRUPTIBLE (UPS)</p> <p><b>PRESS</b><br/>LABORATORY</p> <p><b>PROBE</b><br/>CURRENT<br/>VOLTAGE</p> <p><b>PXI / SCXI MODULE</b></p> <p><b>PYROMETER</b><br/>INFARED<br/>OPTICAL</p> <p><b>RADIOMETER</b><br/>OPTICAL</p> <p><b>RADIOMETER ACCESSORY</b><br/>DETECTOR</p> <p><b>RATEMETER</b><br/>NUCLEAR</p> <p><b>RECORDER</b><br/>ANALOG TAPE<br/>DIGITAL PRINTER<br/>OSCILLOGRAPH (LIGHT BEAM)<br/>OSCILLOGRAPHIC<br/>STRIP CHART<br/>XY</p> <p><b>RECORDER (ENVIRONMENTAL)</b><br/>HYGRO-THERMOGRAPH<br/>TEMPERATURE</p> <p><b>RECORDER/CONTROLLER</b><br/>TEMPERATURE</p> <p><b>REFERENCE JUNCTION</b><br/>TEMPERATURE</p> <p><b>REGULATOR</b><br/>PRESSURE</p> <p><b>RESISTOR</b><br/>DECADE<br/>FIXED<br/>VARIABLE</p> <p><b>ROTARY JOINTS</b><br/>MICROWAVE</p> | <p><b>SCALE</b><br/>PRECISION</p> <p><b>SECTION</b><br/>WAVEGUIDE</p> <p><b>SHORT SHUNT</b><br/><b>SLOTTED LINE</b><br/>MICROWAVE</p> <p><b>SOURCE</b><br/>BLACKBODY<br/>INFARED</p> <p><b>SPECTROPHOTOMETER</b></p> <p><b>SQUARE</b><br/>CYLINDRICAL</p> <p><b>STROBOSCOPE</b><br/>INDICATOR, ANALOG</p> <p><b>SURVEY METER</b><br/>NUCLEAR</p> <p><b>SWITCH</b></p> <p><b>SYCHRO/RESOLVER</b><br/>STANDARD</p> <p><b>TABLE</b><br/>ROTARY</p> <p><b>TEE</b><br/>MICROWAVE<br/>HYBRID</p> <p><b>TELEMETRY</b><br/>RECEIVER</p> <p><b>TELEMETRY ACCESSORY</b><br/>CHANNEL SELECTOR<br/>DEMODULATOR, PHASE<br/>DISCRIMINATOR<br/>SYNCHRONIZER, BIT<br/>TUNER<br/>VCO</p> <p><b>TERMINATION</b><br/>POWER</p> <p><b>TESTER</b><br/>HARDNESS<br/>TENSILE/COMPRESSION<br/>TORQUE</p> | <p><b>TESTER (ELECTRONIC)</b><br/>CURVE TRACER<br/>EDDY CURRENT</p> <p><b>TESTER (ELECTRONIC)</b><br/>ERROR RATE, COMMUNICATION<br/>INSULATION<br/>LOGIC CIRCUIT ANALYZER<br/>LOGIC PROBE<br/>SEMICONDUCTOR<br/>TRANSMISSION LINE</p> <p><b>THERMOMETER</b><br/>DIAL GAGE<br/>DIGITAL<br/>GLASS<br/>INDICATOR, ANALOG<br/>PROBE, RESISTANCE TEMP<br/>PROBE, THERMOCOUPLE</p> <p><b>TIME CODE</b><br/>GENERATOR/TRANSLATOR<br/>TRANSLATOR</p> <p><b>TIMER</b><br/>ELECTRONIC</p> <p><b>TORQUE</b><br/>WRENCH/GAGE</p> <p><b>TRANSDUCER</b><br/>ACCELEROMETER<br/>DISPLACEMENT, ANGULAR<br/>DISPLACEMENT, LINEAR<br/>EXTENSOMETER<br/>LOAD CELL<br/>PRESSURE<br/>TORQUE</p> <p><b>TRANSFORMER</b><br/>CURRENT<br/>ISOLATION<br/>MATCHING<br/>VARIABLE</p> <p><b>TRANSITION</b><br/>WAVEGUIDE TO WAVEGUIDE</p> <p><b>TUNER</b><br/>MICROWAVE</p> <p><b>WEIGHT SET</b></p> |
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***Notes***

- Northrop Grumman is AS9100 certified. Measurements and calibrations are performed in compliance with ANSI/NCSL Z540-1-1994, ANSI/NCSL Z540.3-2006 and/or ISO 17025 based on customer request. Accredited ISO 17025 calibrations are available based on current scope of accreditation based on customer request.
- Measurements and calibrations are directly traceable to NIST (National Institute of Standards and Technology) or other recognized National Standards.
- The ***Uncertainty Values*** listed are for standard calibrations and are intended as a reference only. Actual uncertainties may vary and lower uncertainty values can be achieved in most disciplines upon request.

**DC/LOW FREQUENCY**

| Discipline        | Nominal Value or Range   | Uncertainty   |
|-------------------|--|---|
| <b>AC VOLTAGE</b> | 10 mV<br>10 Hz – 100 kHz   | 0.05 %  |
|                   | 100 mV<br>10 Hz – 40 Hz<br>40 Hz – 20 kHz<br>20 kHz – 300 kHz<br>300 kHz – 1MHz                                  | 0.03 %<br>0.005 %<br>0.03 %<br>0.04 %                         |
|                   | 1 V<br>10 Hz – 20 Hz<br>20 Hz – 40 Hz<br>40 Hz- 100 Hz<br>100 Hz – 20 kHz<br>20 kHz – 100 kHz<br>100 kHz – 1 MHz | 0.02 %<br>0.003 %<br>0.002 %<br>0.002 %<br>0.005 %<br>0.013 % |
|                   | 10 V<br>10 Hz – 20 Hz<br>40 Hz – 100 Hz<br>100 Hz – 20 kHz<br>20 kHz – 100 kHz<br>100 kHz – 1MHz                 | 0.02 %<br>0.003 %<br>0.002 %<br>0.005 %<br>0.013 %            |
|                   | 100 V<br>10 Hz – 20 Hz<br>40 Hz – 20 kHz<br>50 kHz – 100 kHz<br>300 kHz  | 0.02 %<br>0.003 %<br>0.007 %<br>0.013 %                       |
|                   | 1000 V<br>10 Hz – 20 Hz<br>40 Hz – 20 kHz<br>50 kHz – 100 kHz  | 0.02 %<br>0.003 %<br>0.007 %                                  |

**DC/LOW FREQUENCY**

| Discipline        | Nominal Value or Range | Uncertainty |
|-------------------|------------------------|-------------|
| <b>AC CURRENT</b> | 0.01 A                 |             |
|                   | 1 kHz, 10 kHz          | 0.005 %     |
|                   | 0.02 A                 |             |
|                   | 1 kHz, 10 kHz          | 0.005 %     |
|                   | 0.03 A                 |             |
|                   | 1 kHz, 10 kHz          | 0.005 %     |
|                   | 0.05 A                 |             |
|                   | 1 kHz, 10 kHz          | 0.005 %     |
|                   | 0.1 A                  |             |
|                   | 1 kHz, 10 kHz          | 0.005 %     |
|                   | 0.2 A                  |             |
|                   | 1 kHz, 10 kHz          | 0.005 %     |
|                   | 0.3 A                  |             |
|                   | 1 kHz, 10 kHz          | 0.005 %     |
|                   | 0.5 A                  |             |
|                   | 1 kHz, 10 kHz          | 0.005 %     |
|                   | 1.0 A                  |             |
|                   | 1 kHz, 10 kHz          | 0.005 %     |
|                   | 2.0 A                  |             |
|                   | 1 kHz, 10 kHz          | 0.005 %     |
|                   | 3.0 A                  |             |
|                   | 1 kHz, 10 kHz          | 0.005 %     |
|                   | 5.0 A                  |             |
|                   | 1 kHz, 10 kHz          | 0.005 %     |
|                   | 10.0 A                 |             |
|                   | 1 kHz, 20 kHz          | 0.01 %      |
|                   | 20 A                   |             |
|                   | 1 kHz, 10 kHz          | 0.01 %      |
| <b>AC VOLTAGE</b> | 0 – 350V               |             |
|                   | at 1 kHz               | 1 ppm       |

**DC/LOW FREQUENCY**

| Discipline         | Nominal Value or Range  | Uncertainty  |
|--------------------|---|--|
| <b>CAPACITANCE</b> | 1 pF @ 1 kHz<br>10 pF @ 1 kHz<br>100 pF @ 1 kHz<br>1000 pF @ 1 kHz<br>0.01 $\mu$ F @ 1 kHz<br>0.1 $\mu$ F @ 1 kHz<br>1.0 $\mu$ F @ 1 kHz<br>10 $\mu$ F @ 1 kHz<br>Steps of 10 $\mu$ f @ 1 kHz   | 0.0003 %<br>0.0002 %<br>0.0002 %<br>0.0005 %<br>0.05 %<br>0.05 %<br>0.053 %<br>0.25 %<br>.25% per step   |
| <b>INDUCTANCE</b>  | 10 $\mu$ H @ 100 Hz & 1 kHz<br>1 mH @ 100 Hz & 1 kHz<br>10 mH @ 100 Hz & 1 kHz<br>100 mH @ 100 Hz & 1 kHz<br>1 H @ 100 Hz & 1 kHz<br>10 H @ 100 Hz & 1 kHz  | 0.10 %<br>0.02 %, 0.05 %<br>0.02 %<br>0.02 %<br>0.02 %, 0.05 %<br>0.02 %, 0.2 %  |
| <b>RESISTANCE</b>  | 10 $\mu$ $\Omega$ – 100 $\mu$ $\Omega$<br>100 $\mu$ $\Omega$ – 1 m $\Omega$<br>1 m $\Omega$ – 10 m $\Omega$<br>10 m $\Omega$ – 100 m $\Omega$<br>1 $\Omega$<br>1 $\Omega$ – 10 $\Omega$<br>10 $\Omega$ – 100 $\Omega$<br>100 $\Omega$ – 1 k $\Omega$<br>10 k $\Omega$ – 100 k $\Omega$<br><br>100 k $\Omega$ – 1 M $\Omega$<br>1 M $\Omega$ – 10 M $\Omega$<br>10 M $\Omega$ – 100 M $\Omega$<br>100 M $\Omega$ – 1 G $\Omega$<br>1 G $\Omega$ – 10 G $\Omega$<br>10 G $\Omega$ – 100 G $\Omega$<br>100 G $\Omega$ – 1 T $\Omega$<br>1 T $\Omega$ – 10 T $\Omega$ | 10 u $\Omega$ / $\Omega$<br>5 u $\Omega$ / $\Omega$<br>2 u $\Omega$ / $\Omega$<br>1 u $\Omega$ / $\Omega$<br>0.3 u $\Omega$ / $\Omega$<br>0.5 u $\Omega$ / $\Omega$<br>0.5 u $\Omega$ / $\Omega$<br>0.5 u $\Omega$ / $\Omega$<br>1 u $\Omega$ / $\Omega$<br>0.3 u $\Omega$ / $\Omega$<br>2 u $\Omega$ / $\Omega$<br>5 u $\Omega$ / $\Omega$<br>10 u $\Omega$ / $\Omega$<br>15 u $\Omega$ / $\Omega$<br>700 u $\Omega$ / $\Omega$<br>1000 u $\Omega$ / $\Omega$<br>2000 u $\Omega$ / $\Omega$<br>3000 u $\Omega$ / $\Omega$ |

**DC/LOW FREQUENCY**

| <b>Discipline</b>         | <b>Nominal Value or Range</b> | <b>Uncertainty</b> |
|---------------------------|-------------------------------|--------------------|
| <b>PHASE</b>              | 0° - 360° @ 400 Hz            | 0.005°             |
|                           | 0° - 360° @ 50kHz             | 0.005°             |
| <b>FREQUENCY RESPONSE</b> | 0.2 V                         |                    |
|                           | 1.0 – 1 MHz                   | 0.05 %             |
|                           | 10 MHz                        | 0.1 %              |
|                           | 30 MHz                        | 0.2 %              |
|                           | 100 MHz                       | 1.0 %              |
|                           | 1.0 V, 3.0 V                  |                    |
|                           | 0.03 – 1 MHz                  | 0.05 %             |
|                           | 2 – 10 MHz                    | 0.1 %              |
|                           | 20 – 30 MHz                   | 0.2 %              |
|                           | 40 MHz                        | 0.4 %              |
|                           | 60 MHz                        | 0.6 %              |
|                           | 80 MHz                        | 0.8 %              |
|                           | 100 MHz                       | 1 %                |
|                           | <b>RISETIME</b>               | ≤ 14.7 pS          |
| <b>DC VOLT</b>            | 1 uV                          | 10 %               |
|                           | 10 uV                         | 1.0 %              |
|                           | 100 uV                        | 0.1 %              |
|                           | 1 mV                          | 0.01 %             |
|                           | 10 mV                         | 10 ppm             |
|                           | 100 mV                        | 0.8 ppm            |
|                           | 1V                            | 0.5 ppm            |
|                           | 10 V                          | 0.3 ppm            |
|                           | 100 V                         | 0.5 ppm            |
|                           | 1000 V                        | 0.8 ppm            |
|                           | 2000 V                        | 0.02 %             |
|                           | 30000 V                       | 0.02 %             |
|                           | 50000 V                       | 0.02 %             |
| <b>DC CURRENT</b>         | 2 pA                          | 1 %                |
|                           | 20 pA                         | 0.5 %              |
|                           | 200 pA                        | 0.3 %              |
|                           | 2nA – 20 nA                   | 0.07 %             |
|                           | 200 nA                        | 0.04 %             |
|                           | 2 μA – 20 μA                  | 0.03 %             |
|                           | 100 μA – 1A                   | 0.00065 %          |
|                           | 1 A – 10 A                    | 0.005 %            |
|                           | 10A – 100A                    | 0.005 %            |

**RF/MICROWAVE**

| Discipline      | Range           | * Frequency      | Measurement Uncertainty |
|-----------------|-----------------|------------------|-------------------------|
| <b>RF POWER</b> |                 |                  |                         |
| Coaxial         | * 0.01 – 1.0 mW | 0.001 – 67.0 GHz | ±(1.5 – 6.0 %)          |
| Waveguide       | * 0.01 – 1.0 mW | 18.0 – 50.0 GHz  | ±(2.0 – 4.5 %)          |
|                 | * 0.01 – 1.0 mW | 50.0 – 75.0 GHz  | ±(2.0 – 5.0 %)          |
|                 | * 0.01 – 1.0 mW | 75 – 110 GHz     | ±(4.0 – 7.0 %)          |

*\* Other power levels are available upon request*

**RF/MICROWAVE**

| Discipline  | Frequency        | NF Meas. Uncertainty | ENR Measurement Uncertainty |
|---|------------------|----------------------|-----------------------------|
| <b>NOISE FIGURE (NF)/EXCESS NOISE RATIO (ENR)</b> |                  |                      |                             |
| Coaxial   | 0.01 – 50 GHz    | ± 0.10 – ± 0.50 dB   | ± (0.12 dB – 0.55 dB)       |
| Waveguide   | 18 – 50 GHz      | ± 0.25 – ± 0.35 dB   | ± (0.28 dB – 0.40 dB)       |
|   | 50 – 75 GHz      | ± 0.35 – ± 0.75 dB   | ± (0.35 to ± 0.45 dB)       |
| <b>WAVEGUIDE</b>                                  | 18.0 – 26.5 GHz  | ± .25 - ± .30        | ± .25 - ± .35               |
|   | 26.5 – 40.0 GHz  | ± .17 - ± .22        | ± .19 - ± .36               |
|   | 33.0 – 50.0 GHz  | ± .17 - ± .30        | ± .25 - ± .35               |
|   | 50.0 – 75.0 GHz  | ± .20 - ± .35        | ± .22 - ± .45               |
|   | 75.0 – 100.0 GHz | ± .35 - ± .58        | ± .40 - ± 0.70              |

*\* Service is available using Hot and Cold Y-factor techniques for NF (dB0 and ENR (dB).  
NIST service is not available*

**RF MICROWAVE**

| Discipline  | Range  | Measurement Uncertainty                   |
|---|--|---|
| <p><b>NETWORK ANALYSIS</b><br/>All 4 S-Parameters<br/>Magnitude &amp; Phase</p> | <p>300 kHz – 110 GHz</p>                         | <p>Dependent on system used</p>           |
| <p><b>FREQUENCY</b><br/>Cesium Primary Frequency<br/>Standard</p>               | <p>10 MHz, 5 MHz, 1 MHz, 100 KHz<br/>outputs</p> | <p><math>\pm 1 \times 10^{-12}</math></p> |
| <p><b>TIME</b><br/>Relative with respect to GPS</p>                             | <p>1 pps output</p>                              | <p><math>\pm 30</math> n Sec RMS</p>      |



**PHYSICAL**

| Discipline            | Range   | Measurement Uncertainty   |
|-----------------------|---|---|
| <b>FLOW<br/>GAS</b>   | 50 – 50,000 scc/min   | ± 01.15 % of reading (k=2)  |
| <b>VISCOSITY</b>      | Up to 1000 mm <sup>2</sup> /s<br>1000 – 10,000 mm <sup>2</sup> /s<br>Greater than 10,000 mm <sup>2</sup> /s | 0.29% of actual viscosity<br>0.38% of actual viscosity<br>0.44% of actual viscosity |
| <b>MASS</b>           | 10 g – 50 g<br>100 g – 1 kg<br>5 kg – 30 kg   | ± 0.010 mg<br>± 0.050 mg<br>± 1 ppm   |
| <b>FORCE</b>          |   |   |
| Deadweights           | Up to 300 lbf   | ± 0.097% of full scale*   |
| Load Cells            | 0 – 50,000 lbf  | ± 0.1% of full scale* (k=2)   |
| <b>TORQUE</b>         |   |   |
| Transducers           | Up to 1,000 ft lb   | ± .025% of Full Scale   |
| Wrenches/Screwdrivers | 5 – 200 in oz<br>5 – 50 in lb<br>40 – 1,400 in lb<br><br>25 – 600 ft lb                                     | ± 0.033 in-oz<br>± 0.011 in-lbs<br>± 0.39 in-lbs<br>± 0.65 ft-lbs                   |

*\* The combined system uncertainty includes uncertainty as calculated in accordance with ASTM E 74, drift due to temperature variations, drift over time, and indicator uncertainty.*

**PHYSICAL**

| Discipline                         | Range   | Measurement Uncertainty  |
|------------------------------------|---|--|
| <b>VIBRATION</b>                   | 100 Hz, (2 pk g)<br>20 Hz to <100 Hz, (2 pk g)<br>>100 Hz to 2,000 Hz, (2 pk g)<br>>2,000 Hz to 10,000 Hz, (2 pk g) | ± 1.6% (k=2)<br>± 2.1% (k=2)<br>± 1.9% (k=2)<br>± 2.9% (k=2)                     |
| <b>PRESSURE</b>                    |   |  |
| Portable Pressure Calibrator       | 0 – 0.8 in H <sub>2</sub> O<br>0 – 8 in H <sub>2</sub> O  | ± 0.1% of reading + 1 digit<br>± 0.1% of reading + 1 digit                       |
| Capacitance Manometer              | 0.001 – 4 Torr<br>4 – 1000 Torr   | ± 0.004 Torr<br>± 0.1% of reading  |
| Pneumatic Piston Gage              | 0.2 – 25 psi<br>25 – 1,000 psi<br>1,000 – 10,000 psi  | ± 0.0015% of reading<br>± 0.005% of reading<br>± 0.01% of reading                |
| Hydraulic Piston Gage              | 0 – 1,000 psi<br>1,000 – 10,000 psi   | ± 0.011% of reading<br>± 0.06% of reading  |
| Absolute (Ps)<br>Differential (Qc) | 0.5 – 32 in Hg<br>0.5 – 100 in Hg   | 0.003% of FS + 0.005% of reading<br>0.003% of FS + 0.005% of reading             |
| <b>VACUUM</b>                      | 1 E-6 – 1 E-4 Torr  | ± 4.0% of reading (k=2)  |
| <b>LEAK</b>                        |   |  |
| Standard Leak Artifact             | 1 E-7 std cc/s<br>1 E-8 std cc/s<br>1 E-9 std cc/s  | ± 10.1% of reading (k=2)<br>± 10.0% of reading (k=2)<br>± 10.4% of reading (k=2) |

**PHYSICAL**

| Discipline                 | Range   | Measurement Uncertainty  |
|----------------------------|---|--|
| <b>TEMPERATURE</b>         |   |  |
| Bath Calibration           | -195 – 550° C   | ± 0.005° C   |
| Blackbody Source           | 35 – 500° C   | ± 0.5° C   |
| Electrical Substitution    | -270 – 2,300° C   | ± 0.02%  |
| LN2 Comparison Calibrator  | -196° C   | ±0.005° C  |
| <b>Intrinsic Standards</b> |   |  |
| Triple Point of Water      | 0.01 ° C  | ± 0.005° C   |
| Tin                        | 231.9 ° C   | ± 0.08° C  |
| Zinc                       | 419.5 ° C   | ± 0.18° C  |
| Aluminum                   | 660.3 ° C   | ± 0.5° C   |
| <b>HUMIDITY</b>            |   |  |
| Dewpoint                   | -80 - + 20° C   | ± 1° C   |
| Relative Humidity          | 20 – 90% RH   | ± 0.5% RH  |
| <b>GAS ANALYZERS</b>       |   |  |
| Oxygen Analyzers           | 0, 400 ppm<br>10%, 19.5%, 20.9%                               | ± 1% of Stated Value<br>± 1% of Stated Value   |
| <b>AIR VELOCITY</b>        |   |  |
| Thermal Anemometers        | 50 – 250 ft/min<br>250 – 1,500 ft/min<br>1,500 – 6,000 ft/min | ± (2% reading + 2 digits)<br>± (2% reading + 5 digits)<br>± (1% reading + 15 digits) |
| Vane Anemometers           | 50 – 4,000 ft/min   | ± (1% reading + 1 digits)  |
| <b>pH</b>                  | 4, 7, and 10 pH   | ± 0.024 pH (k=2)   |
| <b>CONDUCTIVITY</b>        | 1,000 – 10,000 & 100,000µS/cm                                 | ± 2% at 25° C  |
| <b>NUCLEAR RADIATION</b>   |   |  |
| Gamma Radiation            | 0.013 – 3,500 milliroentgens/hr                               | ± 5.0% of reading  |

### DIMENSIONAL

| Discipline                         | Range  | Measurement Uncertainty  |
|------------------------------------|--|--|
| <b>LENGTH</b>                      |  |  |
| Gage Blocks                        | <0.250 in<br>0.250 – 4.000 in<br>5.000 – 20.000 in                           | $\pm 3.6\mu$ in<br>$\pm 2.2$ in $\pm 0.93$ ppm<br>$4.3+0.18^*L \mu$ in 1 ppm |
| Cylindrical Ring Gages             | 0.10 – 6 in  | $26 \mu$ in  |
| Cylindrical Plug Gages             | 0.01 – 6 in  | $5 \mu$ in $\pm 1$ ppm   |
| Outside Micrometers                | 0.5 – 20 in (any inch)   | $\pm 0.00005$ in   |
| Inside Micrometers                 | 0.1 – 6 in (any inch)  | $\pm 0.0001$ in  |
| Vernier Gages                      | 0.01 – 36 in (any inch)  | $\pm 0.0001$ in  |
| Measuring Microscopes              | 0.01 – 3.0 in (Glass scale)  | $\pm 0.0001$ in  |
| Coordinating Measuring<br>Machines | Scales to 17 in<br>Ball Bar Test   | $\pm 0.00001$ in $\pm 1.7$ ppm<br>$\pm 0.0001$ in                            |
| Thread Plug & Set Gages            | 4 – 80 pitch   | $\pm 0.00005$ in   |
| Thread Wires                       | 4 – 80 pitch   | $\pm 18.3 \mu$ in  |
| Scales (metal)                     | Up to 12 ft  | $\pm 0.0003$ in / ft   |
| <b>SURFACE ROUGHNESS</b>           |  |  |
| Surface Roughness Systems          | 0.000001 – 0.0001 in Ra<br>0.0001 – 0.001 in Ra                              | $\pm 2.5 \mu$ in Ra<br>$\pm 4 \mu$ in Ra                                     |
| Surface Roughness Standards        | 0.000001 – 0.0001 in Ra<br>0.0001 – 0.001 in Ra                              | $\pm 7.3 \%$<br>$\pm 7.3 \%$   |
| <b>ROUNDNESS</b>                   |  |  |
| Cylindrical Squares                | 0.5 – 6 in   | $\pm 11.6 \mu$ in  |
| <b>FLATNESS</b>                    |  |  |
| Optical Flats                      | All Standard Sizes<br>(Plano-Interferometer)                                 | $\pm 0.63 \mu$   |
| Surface Plates<br>Plate/Anvils     | All Standard Sizes<br>All via Electronic Height Gage<br>and AA Surface Plate | 0.000060 in / ft<br>$\pm 0.00005$ in   |
| <b>OPTICAL-DIMENSIONAL</b>         |  |  |
| Theodolites                        | 0 – 360 degrees  | $\pm 2$ arcsec   |
| Jig Transits                       | 0 – 360 degrees  | $\pm 5$ arcsec   |

**DIMENSIONAL**

| Discipline   | Range  | Measurement Uncertainty   |
|--|--|---|
| <p><b>ANGLE</b></p> <p>Angle Gage Blocks<br/>           Rotary Tables<br/>           Autocollimators<br/>           Levels<br/>           Sine Bars<br/>           Optical Cubes<br/>           12 Sided Optical Polygons</p> <p><b>HARDNESS</b></p> <p>Rockwell Hardness<br/>           Testers</p> | <p>1 sec – 45 degrees<br/>           0 – 360 degrees<br/>           0 – 20 arcmin<br/>           0 – 20 arcsec<br/>           0 – 20 arcmin<br/>           90 degrees<br/>           0 – 360 degrees</p> <p>0.1 – 100 pts Rc<br/>           (B, C, E, N, &amp; T Scales)</p> | <p>± 0.54 arcsec<br/>           ± 0.63 arcsec<br/>           ± 0.2 % of reading<br/>           ± 0.5 arcsec<br/>           ± 0.5 arcsec<br/>           ± 1.6 arcsec<br/>           ± 0.5 arcsec</p> <p>± 1.0 -2.0 pts Rc *</p> <p>varies with test specimen</p> |

*\* Traceable to NIST via force, rate of application and depth. (Hardness Test Specimens)*

**ELECTRO-OPTICS/FIBER OPTICS**

| Discipline                              | Range   | Measurement Uncertainty |
|---|---|-------------------------|
| <b>LASER POWER</b><br>Laser Power Meter | 632.8 nm  | ± 1.09%                 |
| Laser Power Meter                       | 10 $\mu$ W – 3 mW                                 |                         |
| (Electrical Substitution)               | Flat Response<br>1 mW – 50 W                      | ± 0.5%                  |
| <b>SPECTRAL RESPONSIVITY</b>            | 200nm   | ± 6.0%                  |
|   | 205nm - 215nm                                     | ± 4.0%                  |
|   | 220nm – 260nm                                     | ± 1.2%                  |
|   | 265nm – 345nm                                     | ± 1.1%                  |
|   | 350nm – 380nm                                     | ± 0.50%                 |
|   | 385nm – 450nm                                     | ± 0.35%                 |
|   | 455nm – 950nm                                     | ± 0.20%                 |
|   | 955nm – 1000nm                                    | ± 0.78%                 |
|   | 1005nm – 1050nm                                   | ± 1.50%                 |
|   | 1055nm – 1100nm                                   | ± 2.5%                  |
| <b>PHOTOGRAPHIC STEP<br/>TABLET</b>     |   |                         |
| Optical Density                         | 0.05 OD – 4.3 OD                                  | ± 0.02 O.D. or ± 1.1%   |
| <b>DENSITOMETERS</b>                    |   |                         |
| Optical Density                         | 0.05 OD – 4.3 OD                                  | ± 0.02 O.D. or ± 1.1%   |
| <b>NEUTRAL DENSITY FILTERS</b>          |   |                         |
| Optical Density                         | 0.01 OD – 10.0 OD                                 | ± 0.005 OD              |
| <b>COLOR FILTERS /<br/>INTERFERENCE</b> |   |                         |
| Transmission                            | 300nm – 1700nm                                    | See Spectral Irradiance |
| <b>PHOTOMETRY</b>                       |   |                         |
| Illuminance (footcandle)                | 0.5 fc - 4000 fc                                  | ± 1.45%                 |
| Illuminance (Lux)                       | 5 Lux - 43000 Lux                                 | ± 1.45%                 |
| Luminance (footlambert)                 | 1 fl - 500 fl                                     | ± 1.52%                 |
| Luminance (cd/m <sup>2</sup> )          | 3.426 cd/m <sup>2</sup> - 1700 cd/m <sup>2</sup>  | ± 1.52%                 |
| <b>COLORIMETRY</b>                      |   |                         |
| Chromaticity coordinates                | 432nm - 647nm                                     | ± 1.0 nm                |
| <b>ULTRA-VIOLET (UVA)</b>               |   |                         |
| Irradiance, 365nm                       | 1 $\mu$ W/cm <sup>2</sup> - 28 mW/cm <sup>2</sup> | ± 1.94%                 |

**ELECTRO-OPTICS/FIBER OPTICS**

| Discipline  | Range  | Measurement Uncertainty                    |   |
|---|--|--|---|
| <b>SPECTRAL IRRADIANCE</b>  | 300nm – 500nm  | ± 1.83%                                    |   |
|   | 500nm – 750nm  | ± 1.56%                                    |   |
|   | 750nm – 1100nm   | ± 2.05%                                    |   |
|   | 1100nm – 1500nm  | ± 1.89%                                    |   |
|   | 1500nm – 1700nm  | ± 2.26%                                    |   |
| <b>FIBER OPTIC</b><br>F/O Power Meter<br>Accuracy<br>Single Mode, Multi-Mode  | FP 860 nm,<br>-5 – -50dBm  | ± 1.23%                                    |   |
|   | FP 1303nm,<br>-5 – -50dBm  | ± 1.18%                                    |   |
|   | FP 1545nm,<br>-5 – -50dBm  | ± 1.17%                                    |   |
|   | DFB 1450nm – 1550nm,<br>+3 – -50dBm                                | ± 1.17%                                    |   |
|   | F/O Laser Source<br>Output Power<br>Single Mode, Multi-Mode        | 600nm – 1550nm<br>+10 – -50dBm             | ± 1.18%   |
|   | Wavelength Accuracy  | 600nm – 700nm<br>700nm – 1650nm            | ± 0.16%<br>± 0.0003%                                |
|   | F/O Attenuator<br>Accuracy<br>(see power meter wavelengths)        | 0dB – -60dB                                | ± 0.01dB  |
|   | Insertion Loss   | 0dB – -60dB                                | ± 0.08dB  |
|   | Repeatability  | 0dB – -60dB                                | ± 0.008dB   |
|   | F/O Optical / Electrical Converter<br>Power monitor<br>Pulse Width | 1303nm<br>1300nm                           | (Call for specific capability)<br>± 1.18%<br>≤ 40ps |
| F/O Optical Spectrum Analyzer<br>Wavelength<br>Amplitude  | 632.8nm<br>860nm, 1450 – 1550nm                                    | Natural Physical Constant<br>± 0.0003%     |   |
|   | 632.8nm / 860nm, 1450 – 1550nm                                     | ± 1.18%                                    |   |
| <b>GLOSS / REFLECTANCE</b><br>Specular Gloss  | 1.5 GU – 30.3 GU   | ± 2 GU                                     |   |
|   | 6.9 GU – 40.7 GU   | ± 2 GU                                     |   |
|   | 85.8 GU – 99.3 GU  | ± 1 GU                                     |   |
| <b>ACCOUSTICS</b><br>Sound Level Meter (type0,1,2)<br>A,B,C,Lin weighting Accuracy<br>(125Hz – 2000Hz)<br>Linearity | 110dB  | ANSI S1.6-1967, ± 0.11 dB                  |   |
|   | -80 dB – 130 dB  | ± 0.11 dB                                  |   |
|   | Sound Pressure Level Calibrators<br>Sound Pressure Level           | -80 dB – 130 dB                            | ± 0.11 dB   |
|   | Frequency<br>Distortion (THD)                                      | 125Hz – 2000Hz<br>-80 – 0 dB (.01 to 100%) | ± 0.01%<br>± 1.0 dB                                 |

**SPECIAL ENGINEERING CAPABILITIES**

| <b>PHASE NOISE</b>   |  |
|--|--|
| Automated Phase Noise  | Fully automated Phase Noise measurements are performed using the HP/Agilent E5504 system supplemented by the HP/Agilent 8566B. The HP/Agilent E5504 covers the base band ranges: 0.01 Hz to 100 MHz. The HP/Agilent 8566B is used to extend the base band range to 800 MHz.                                      |
| Two Oscillator Technique   | RF frequency is limited by the availability of a reference oscillator. The HP/Agilent 8663A/70427A is used at RF frequencies to 26.5 GHz. Capability is enhanced if better reference oscillators are provided. State-of-the-art 5 MHz oscillators are available offering – 128 dBc/Hz at 1 Hz Fourier frequency. |
| Single Oscillator  | Variations of the Single Oscillator (FM Discriminator) can measure at RF frequencies from 200 MHz to the millimeter wave, waveguide bands.   |
| * <b><i>Measurement uncertainties for special measurements shown vary with test and/or test configuration.</i></b> |  |



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