# Design, installation, and operation of scientific equipment on NOAA WP-3D aircraft for ESRL CSD air quality and climate programs

### Introduction

This document is a guide for researchers for the design, installation, and operation of scientific instrumentation aboard the NOAA WP-3D aircraft during SENEX2013. This guide applies to all installed equipment, custom-built or commercial. It also provides information to scientists about acceptable practices. Necessary information, drawings, and engineering specs for P-3 installation are available on the CSD integration [web site](http://esrl.noaa.gov/csd/groups/csd7/measurements/2013senex/P3/integration/).

Scientists should provide information to NOAA AOC (Aircraft Operations Center) on their respective instruments by October 5, 2012. Appendix 1 outlines the needed documentation, which consists of (1) a general P3 installation worksheet, (2) a weights and balance worksheet and (3) a scientific instrument description.

AOC engineers and techs must approve each installation. Following the guidelines and practices outlined in this document will reduce delays and ease the integration and approval process. It is the responsibility of all the researchers to comply with AOC requirements, and their personnel will assist in interpreting these guidelines to assure conformity. Communications with AOC should be coordinated by the CSD Aircraft Instrument Coordinator (AIC): Carsten Warneke (303-497-3601 or [email](mailto:carsten.warneke@noaa.gov)) or the mission scientist: Joost de Gouw (303-497-3878 or [email](mailto:Joost.deGouw@noaa.gov)). Early and frequent communication with the AIC is highly recommended for the approval and integration process.

### Design load criteria

All fuselage-mounted equipment must be installed within the various instrument racks or be secured to existing attachment points. Fuselage-mounted equipment must be demonstrated to be able to withstand the larger of the ultimate flight load or the crash load, where load = weight x load factor. Load factors specific to the WP-3D aircraft are given in Table 1.

Table 1. Equipment design load factors.

|  |  |  |
| --- | --- | --- |
| **Direction** | **Flight load factor** | **Crash load factor** |
| Forward | - | 10 g |
| Up | 4.2 g | 2 g |
| Down | 7.1 g | 5 g |
| Lateral | 1.9 g | 1.5 g |

Data from “NOAA Stress Analysis Worksheets WP-3D”

(Lockheed Corp.)

In addition, externally mounted equipment must also be able to withstand aerodynamic loads, calculated based on size and shape for sea-level pressure and a maximum speed of 300 knots. The Data and Development Branch at AOC will assist in the interpretation of these criteria.

Equipment weight limits for fuselage-installed instrumentation varies by location, and maximum acceptable weight and overturning moment data are listed in Appendix 2 together with the relevant aircraft locations.

WP-3D racks accept 19”-standard rack mount cases, which can be obtained from many different manufacturers. User-supplied rack-mounted equipment should be fully enclosed within such cases whenever possible, and case structural integrity and method of mounting to the rack will be subject to inspection by AOC personnel. When equipment is not fully contained within an enclosure, the PI may be required to provide an engineering analysis documenting the ability to withstand the relevant loads using the factors listed in Table 1. Rack-mounted equipment boxes weighing more than 12 lbs. must sit on support rails, or directly on another box supported by rails, within in the instrument rack.

Finally, please keep in mind that the only entrance for loading equipment into the fuselage is the aircraft cabin door, which is 27” wide.

### Materials

The pressurized WP-3D aircraft environment can subject scientific equipment to extremes of vibration, shock, heat, and electrical instability. Acceptable designs incorporate a demonstrable margin of safety using aircraft-compatible materials without undue weight gain. Commonly accepted materials for aircraft structural elements include heat-tempered (T5 or higher) aluminum alloys 2024, 6061, and 7075. If a structural aluminum part is welded, it must be subsequently heat-treated to T5 or higher temper before it will be accepted. Steel alloy 4130, and stainless steel alloys 301, 302, 304, and 316 are acceptable for structural parts. Other materials such as copper, brass, plastics, iron, and non-tempered aluminum may not be used for structural members. Please be prepared to verify aluminum alloy material on request; aluminum stock purchased from hobby or hardware stores is often not acceptable for structural use in aircraft. Use of extruded aluminum framing (e.g., 80/20) for structural installations is not allowed; please contact the [AIC](mailto:carsten.warneke@noaa.gov?subject=80/20) with any questions.

Structural welds (inlet fairings, rack corner joins, etc.) must be performed either by an FAA-certified welder, or by a non-certified welder and subsequently approved by an FAA-certified inspector. In the Boulder area, vendors providing this service include:

|  |  |  |
| --- | --- | --- |
| **Aviation Welding Technology Inc.** | **Advanced Aviation Services** | **Aero Systems Inc.** |
| 1116 Colorado Avenue | 3760 Wheeling St. Suite #11 | 2580 S. Main St. |
| Longmont, CO 80501 | Denver, CO 80239 | Erie, CO 80516 |
| (303) 776-2810 | (303) 371-7579 | (303) 665-9321 |
| (303) 682-5911 fax | (303) 371-0109 fax | (303) 665-6367 fax |
|  |  | [www.asicolorado.com](http://www.asicolorado.com/) |

Design input from the welder should be solicited prior to any machining for proper weld preparation and materials selection.

### Fasteners

Electronics racks, seats, and other substantial scientific equipment are secured to the floor and/or sidewall using heavy-duty extruded cargo tracks (Brownlines) and 5/16” stud fasteners; the necessary hardware is provided by AOC. These fasteners can be repositioned in 1” increments fore-aft in the aircraft. The Brownline locations are shown in the fuselage drawings available on the P-3 integration [web site](http://esrl.noaa.gov/csd/groups/csd7/measurements/2013senex/P3/integration/).

Aircraft-rated fasteners (MS, AN, or NAS standards) such as screws, nuts, bolts, and rivets, must be used for all structural assembly. All threaded structural fasteners must be secured by self-locking nuts, self-locking inserts, or safety wire. Rivets or through-holes accepting a bolt, washer, and locking nut are preferred over blind tapped holes. Because of taper at the ends, installed structural bolts and screws must project by two complete threads for full rated strength. Locking steel inserts (Helicoils, Keen-serts, etc.; available from [McMaster-Carr](http://www.mcmaster.com/)) must be used for structural tapped holes in aluminum.

Whenever possible, aircraft-rated fasteners should be used for other, non-structural elements of the equipment as well. When flat-head, countersunk fasteners are used, the 100° countersink is preferred over the 82° countersink. These and many other aircraft-rated fasteners can be ordered online from a number of vendors, e.g., [Genuine Aircraft Hardware](http://www.gen-aircraft-hardware.com/), [Aircraft Spruce](http://www.aircraft-spruce.com/), and [Wicks Aircraft Supply](http://www.wicksaircraft.com/).

Threaded fasteners on standard vacuum fittings without positive locking designs, such as KF or ISO clamps, must be secured by safety wire or a simple tie-wrap to prevent loosening under vibration. When properly seated, compression fittings such as Swagelok, Gyrolok, Parker etc. are under tension by design and do not normally require additional locking hardware for safe installation.

**Weight**

With nearly three tons of scientific instruments installed in the fuselage, the full CSD payload is at the maximum zero-fuel weight permitted for NOAA WP-3D aircraft. Each PI should make it a priority to continue to work towards cost- and time-effective ways of minimizing the space and weight of instrumentation. Some instruments can shed weight more easily than others, and unfortunately there are no hard and fast guidelines to use in making these decisions.

As an example, ca. 10-lb savings have often been realized by switching from steel to aluminum compressed gas cylinders, and from steel to aluminum regulators, with no detriment to a given measurement. A ca. 250-lb savings is afforded by automating an instrument that would otherwise have required an operator. However, modifications for weight reduction should be rigorously evaluated to ensure that scientific data quality is not compromised. Further, weight inappropriately removed from a structural part has often proved very costly in time and resources, so please consult with the [AIC](mailto:carsten.warneke@noaa.gov) before trimming “excess” material from structural members.

Fuselage instrument weight is a zero-sum game; if one-instrument gains, that weight must be reduced on a different instrument elsewhere. We will work with each PI to evaluate potential instrument weight savings measures, while considering the attendant cost in time and resources. Please feel free to discuss ideas with the [AIC](mailto:carsten.warneke@noaa.gov?subject=payload%20weight%20savings) if you are interested in assessing weight reduction steps for your instrumentation.

*Weight and balance information.* Weights and locations of installed equipment must be documented before being brought on board, so the aircraft weight and center of gravity can be correctly calculated. Location is given by flight station (FS) in inches from the aircraft nose; FS locations are marked every 10” on the fuselage seat tracks. During integration, a weight-and-balance log sheet is provided, and can be found next to a calibrated scale at the foot of the aircraft ladder. We are required to log the weight of each component, or assembly of components, prior to bringing it up the ladder. Subsequent changes to those logged weights must also be clearly documented in the log, e.g., if an electronics box is removed for servicing. Items temporarily brought on board, but that will not be installed for flight – e.g., tools and parts boxes – should not be logged. Please help by summing weights into as few entries as possible; a single entry of “populated Station 3 rack, 525 lbs., FS 540” is much preferred to a dozen or so entries for individual items within the rack.

Additional weight-and-moment information must be provided for equipment installed in the fuselage. Spreadsheet templates, specific to standard racks and their fuselage locations, are available for download from the P-3 integration [web site](http://esrl.noaa.gov/csd/groups/csd7/measurements/2013senex/P3/integration/). Weight and overturning moment maximum limits for standard equipment locations are given in Appendix 2. PIs with equipment in non-standard racks and locations will need to provide similar information on weights and overturning moments. Completed rack weight-and-balance spreadsheets should be turned in along with the P-3 Installation Worksheet (Appendix 1) to the [AIC](mailto:carsten.warneke@noaa.gov?subject=rack%20moment%20worksheet).

### Electrical Power

*Wiring*. The following wire insulation materials are acceptable for scientific equipment installed in the aircraft: PVDF (Kynar), PTFE (Teflon), ETFE (Tefzel), and TKT (Teflon/Kapton/Teflon). Unacceptable insulation materials include PVC, Nylon, or Kapton. Wire meeting the M22759/34 or /41 standards is required for permanent aircraft wiring installation. Wire size relative to current-carrying capacity is a safety concern and the guidelines in Table 2 (copper conductor circuit ratings) and Table 3 (crimp contactor ratings) may never be exceeded.

Table 2. Copper wire and circuit protector chart.

|  |  |  |
| --- | --- | --- |
| AN gauge copper wire | **Circuit breaker (A)** | **Fuse (A)** |
| 24 | 2.5 | 3 |
| 22 | 5 | 5 |
| 20 | 7.5 | 5 |
| 18 | 10 | 10 |
| 16 | 15 | 10 |
| 14 | 20 | 15 |
| 12 | 25 | 20 |
| 10 | 35 | 30 |
| 8 | 50 | 50 |
| 6 | 70 | 70 |

*Basis of Table 2:*

*(1) Wire bundles in 135F. ambient and altitudes up to 30,000 feet.*

*(2) Wire bundles of 15 or more wires, with wires carrying no more than 20% of total current carrying*

*capacity of bundle as given in Specification MIL-W-5088 (ASG).*

*(3) Protectors in 75 to 85 F. ambient.*

*(4) Copper wire Specifications MIL-W-5088.*

*(5) Circuit breaker to Specifications MIL-C-5809 or equivalent.*

*(6) Fuses to Specifications MIL-F-15160 or equivalent.*

Table 3. Current load limits for crimp contacts.\*

|  |  |  |
| --- | --- | --- |
| wire gauge | **Contact size** | **Max. current (A)** |
| 24 | 20 | 3 |
| 20 | 20 | 7.5 |
| 20 | 16 | 7.5 |
| 16 | 16 | 13 |
| 14 | 12 | 17 |
| 12 | 12 | 23 |
| 10 | 10 | 33 |
| 8 | 8 | 46 |

\*Assumes stranded copper wire with Teflon insulation and crimp contactors.

Contact information up to AWG 12 from PV MIL-C-26482 Series II

handbook. Hermetic seal contactors must be derated according to the

MIL-C-26482 (or relevant connector) handbook guidelines.

Please note that wiring using crimp contacts must be protected at or below the ratings given in table 3. For example, 16 gauge wire can be protected using a 15 Amp circuit breaker or a 10 Amp fuse (Table 2), but 16 gauge wire with crimp contacts must be protected at or below 13 Amps (Table 3). In practice, this might dictate a 10 Amp breaker, as 13A commercial breakers are not readily available.

All line power must be individually switched and fused appropriate to the load and power cord rating. One convenient solution is the Tyco Electronics W23-X1A1G-xx series thermal circuit breaker, available online from [Newark](http://www.newark.com/), [Wicks Aircraft](http://www.wicksaircraft.com/), or [Allied Electronics](http://www.alliedelec.com/).

Workmanship of wiring in user-supplied equipment must be of high quality throughout. Exposed conductors are not permitted, and the use of appropriate connector covers, backshells, and shrink-wrap is mandatory. Electrical connectors should be strain-relieved and wires should be neatly bundled whenever possible. Wiring bundles, both internal and external to the instrumentation enclosure, must be neatly routed, strain-relieved, and protected against chafing, e.g., by routing through nylon loom clamps (see Figure 1). Wires or wiring bundles may not be tie-wrapped directly to the rack frames.



Figure 1. Nylon clamp for cable routing ([NMC](http://www.nmcgroup.com/aviation_clamps.htm)).

Cabling specific to the aircraft installation is highly recommended, to minimize excess length and to eliminate strained connections. Materials and workmanship within user-supplied electronics boxes must be of the same quality as that expected of external wiring. Instrument PIs may be asked to provide circuit diagrams and Underwriter’s Laboratories (UL) certification for commercially purchased components at AOC discretion. User-supplied or commercially purchased equipment with substandard wiring will be repaired by the user and reinspected by AOC personnel prior to installation in the aircraft.

A locking feature is highly recommended for all power and signal connectors, to prevent unintended disconnects caused by vibration during flight. Suggested connectors for new design are the MIL-C-26482 Series 2 circular connectors with backshell and strain relief for power lines. Additionally, these connectors, BNC, or locking D-sub connectors can be used for signal lines. Crimp-style connections are generally recommended over solder connections. Circular, BNC, and locking D-sub connectors, their strain reliefs, backshells, and mating components (as well as crimp, insertion, and removal tools) can be easily obtained from numerous vendors including [Newark](http://www.newark.com/), [Digikey](http://www.digikey.com/), [Conec](http://www.conec.com), and [Allied](http://www.alliedelec.com/). Dedicated vendors of circular connectors include the following:

|  |  |
| --- | --- |
| **Circular Connectors, Inc.** | **PEI-Genesis** |
| 3250 Corte Malpaso | 2180 Hornig Road |
| Camarillo, CA 93012 | Philadelphia, PA 19116 |
| (805) 987-8145 | (888) 349-9787 |
| (805) 987-8556 fax | (215) 552-8041 fax |
| [www.circularinc.com](http://www.circularinc.com) | [www.peigenesis.com](http://www.peigenesis.com) |

For instruments that share a single rack, it is good practice to provide a single, easily accessible, and clearly labeled circuit breaker to shut off power to each instrument independently of the others.

*Heaters.* Heated parts must have adequate thermal shielding to protect personnel from injury, and to prevent damage or ignition of surrounding materials. Good safety practice is to have a passive thermostat in series and in thermal contact with the heated unit. The thermostat is chosen to open at a temperature above the typical setpoint of the heated device, to limit potential hazards from a shorted or runaway heater controller. Surface-mounted thermostats can be obtained from [Airpax](http://www.airpax.net/site/sensing/bimetal/index.html) and from distributors of [Honeywell](http://content.honeywell.com/sensing/prodinfo/thermostats/bimetalthermostat.asp) temperature sensors.

*Power on the aircraft*. To minimize the risk of fire, scientific power is only available when an AOC crewmember is aboard the aircraft; all instruments must be fully powered down when unattended, with UPS power off. No instruments may be powered overnight. On flight days, power is available 3 hours before takeoff for instrument warmup, and 1 hour postflight for instrument shutdown. On non-flight days power is usually available during designated working hours. In the field, to permit AOC crew rest, at least one day a week is designated as a “hard down day” with zero aircraft access or power; please plan accordingly.

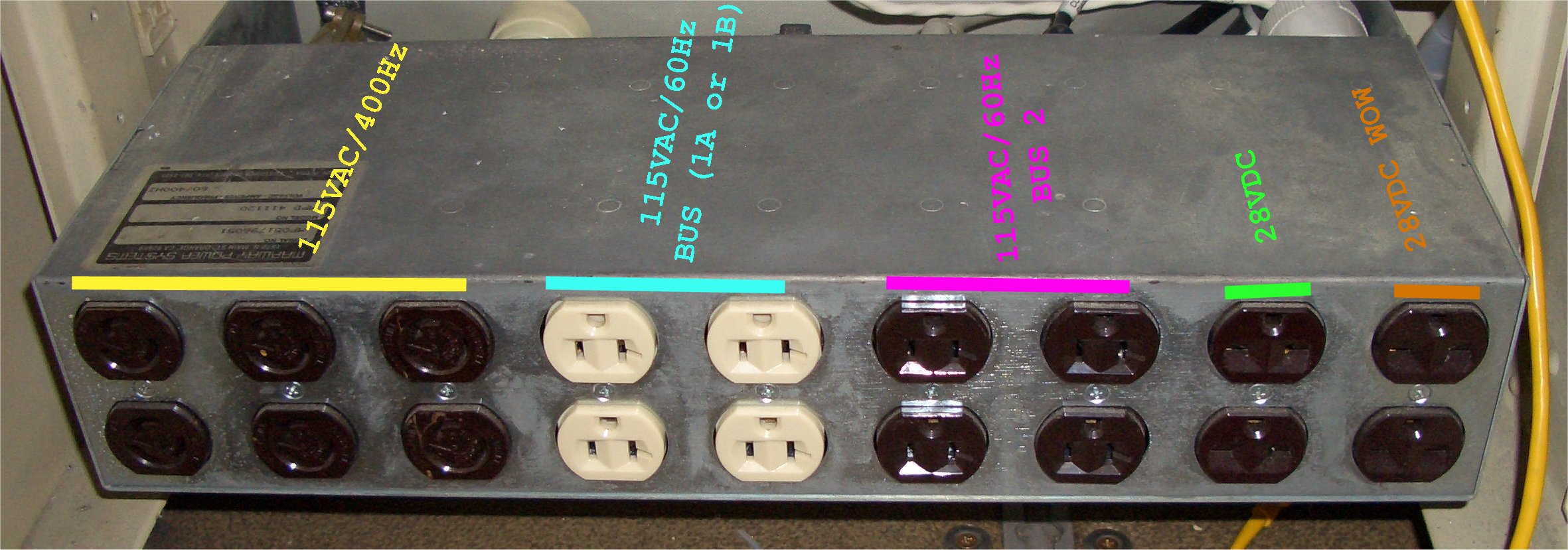
Scientific power aboard the aircraft can be sourced externally, from either the hangar electrical supply or a diesel-powered ground cart, or internally, from the auxiliary power unit (APU) or from the #2 engine. Switching between these sources occurs on flight days; before takeoff, power source sequence is typically (ground cart –> APU –> #2 engine), and after landing (#2 engine –> APU –> ground cart). Each power source is subject to instability or failure (hangar loses power, ground cart runs out of fuel), and glitches or outages in switching over from one source to another are common. The 115V 60Hz single-phase service is especially unstable during power switchover.

Good instrument design takes these power instabilities into account so that scientific equipment is fault-tolerant, i.e., not disrupted by short-term (<1sec) electrical transients or damaged by longer-term outages. Experience has shown that rack-mount computers are highly sensitive to switching transients and should not be plugged into the 60Hz bus. Standard rack-mount computer power supplies seem to accept 400Hz power without a problem. Laptops can be plugged into either 60Hz or 400Hz, as the internal batteries seem to make laptops electrically fault-tolerant.

Scientific power distribution is controlled by the flight crew; during emergencies, the flight crew may disconnect scientific power without warning. Count on at least one (and likely several) unanticipated power-off events during each project. Designing and thoroughly testing a simple power fault recovery procedure BEFORE installation on the aircraft is highly recommended. This is especially important for unattended instruments, for which this procedure would be carried out by other PIs on board.

### Fuselage power distribution

### Scientific electrical power in the cabin is typically provided via AOC-standard Marway power distribution boxes using NEMA receptacles, each rated at 15 Amps max (Figure 2). Standard rack power through these boxes is 115V 60Hz from either Bus 1A or 1B (depending on location in the aircraft), 115V 60Hz from Bus 2, 115V 400Hz, 28VDC, and 28VDC weight-on-wheels (WOW).



### Figure 2. Marway power distribution box (receptacles on other face not shown).

Table 4. WP-3D scientific power.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Service** | **Total available (Amps)** | **Typical at each rack**  **(Amps)** | **Bus Imax (Amps)** | **NEMA plug1** | **Number of receptacles1** |
| 115V 60Hz | 105 | 15 | 1A: 35  1B: 35  2 : 35 | 5-15P | 16 |
| 115V 400Hz | 150 | 15 | A: 50  B: 50  C: 50 | L5-15P | 10 |
| 115V 400Hz 3Ø | 35 | N/A | 35 | N/A | N/A |
| 28VDC | 150 | 15 | 1A: 50  1B: 50  2A: 50 | 6-15P | 4 |
| 28VDC WOW2 | 50 | 15 | 2B: 50 | 6-20P | 4 |

1 for Marway distribution box shown in Figure 2.

2 WOW power is OFF when weight is on landing gear.

Custom designs for electrical power distribution offer rack space and weight savings, at some cost in time and materials; these designs must be approved by AOC engineers prior to use in the aircraft. Please contact the [AIC](mailto:carsten.warneke@noaa.gov?subject=P3%20rack%20electrical%20distribution) if you wish to explore alternatives to the standard Marway distribution box shown in Figure 2.

Three-phase (3Ø) 400Hz power is separately available at specific locations in the fuselage, and is typically used for large electrical motors on vacuum pumps. Motors above ½ HP (93W) must be thermally and electrically protected. Standard P-3 400Hz 3Ø connector and wiring diagram information is available on the integration [web site](http://esrl.noaa.gov/csd/groups/csd7/measurements/2013senex/P3/integration/).

Electrical usage by previous CSD payloads suggest that most of the 400Hz power (single-phase or three-phase) is currently used. At present, the most headroom remains on the 60Hz and 28VDC buses, and researchers are encouraged to use these where possible. For converting aircraft 28VDC to other forms, DC-DC converters (e.g., the ComPAC line from [Vicor](http://www.vicorpower.com)) and DC-AC inverters (e.g., the aircraft-rated 28V inverter from [AeroMedix.com](http://aeromedix.com/), click on “power accessories”; the Samlex 24V inverters available at [Don Rowe Inc.](http://www.donrowe.com/inverters/24vdc_inverters.html) also accept 28V DC input) are commercially available.

### Wing station power distribution

Standard scientific power at wing stations is 115V 400Hz and 28VDC; in addition, 400Hz 3Ø power is available for the AMPS pod at Station 15 (RWS 83). Other power requirements (e.g., 115V 60Hz or 28VDC WOW) may be available at particular wing stations on a limited basis; these requests must be communicated to AOC engineers well in advance of instrument integration.

*Additional electrical power guidelines:*

•60Hz inductive loads, such as motors, should be fed from Bus 2.

•DC motors must be brushless to avoid arcing.

•Use of high-voltage equipment (lasers, CRTs, channeltrons, etc.) in unpressurized external pods requires additional care to prevent arcing at low pressures. These installations must be designed and certified to safely operate at pressures down to 250 Torr.

•Grounding must be accomplished by a connection to aircraft power ground; the use of a chassis ground to the airframe is not acceptable.

### Data distribution in flight

Sharing data between different systems is valuable for several reasons, including operator situational awareness, monitoring systems status remotely, and recording supplemental data generated external to a given instrument.

*Aircraft data.* Aircraft flight-level data (e.g., position, speed, winds, ambient pressure, ambient temperature, water vapor, etc.) are available via Ethernet or serial data stream. A Network Time Protocol (NTP) server is available on the aircraft network at 10.43.16.10 for client synching to the aircraft-standard GMT time. Time information is also available in the older IRIG-B format. [Ken Aikin](mailto:Kenneth.C.Aikin@noaa.gov?subject=P-3%20data%20and%20timing%20question) of ESRL CSD/CIRES can help answer questions about software configuration to read these inputs. Instrument software should be designed to be tolerant of occasional aircraft data signal interruption.

A limited number of analog outputs from individual instruments can be recorded by the aircraft data station, if requested prior to integration on the P-3 Installation Worksheet (Appendix 1) that accompanies this Guide.

*Chemical and aerosol data.* Selected chemical data (e.g., SO2, CO, O3, NOy, particle number, etc.) are available on the aircraft network for instruments running a standardized version of DaqFactory (DF) control software.

*Communications to the ground.* While in flight, a satellite data link is used for messaging via Xchat, permitting up to three different user computers aboard the aircraft to be in text communication with the ground.

### Environment

*Vibration and shock isolation*. Turboprop aircraft in the daytime convective boundary layer are subject to relatively high levels of vibration and, to a lesser extent, shock. Depending on the application, researchers may choose to isolate individual subassemblies, rackmount boxes, or entire racks. Wire-rope isolators, for some of which ultimate load data are available, can be obtained directly from [Enidine](http://www.enidine.com/); this brand is recommended for structural isolation mounts. Non-structural isolators (for minor components within enclosures) are also available from [Barry Controls](http://www.barrycontrols.com/defenseandindustrial/isolatorselectionguide/). Tutorials on isolator selection are available from these websites. When in doubt, please consult with the [AIC](mailto:carsten.warneke@noaa.gov) or AOC techs before selecting a vibration mount design and product.

*Temperature*. The aircraft environment is subject to extremes of heat and cold, and careful thought regarding temperature management will always pay off. Overheating has been a chronic and serious issue for many instruments in the WP-3D fuselage, and pod instrumentation running on the ground on a warm, sunny day is also subject to this problem. Cabin temperatures are location-dependent; measured electronics rack temperatures have approached 40° C (104° F) in previous deployments, with higher temperatures measured inside of enclosed electronics equipment. Data on rack and cabin temperatures is available on the P-3 integration [web site](http://esrl.noaa.gov/csd/groups/csd7/measurements/2013senex/P3/integration/).

Forced air cooling, using lightweight brushless DC fans – e.g., the Flite II series from Comair-Rotron - can be very effective (up to a point) and is generally recommended. AOC is working on the cabin cooling issue, but with scientific equipment dissipating 25kW of energy within the fuselage, positive airflow through instrumentation enclosures is often necessary to keep things running properly in an otherwise hot cabin.

### Hazardous materials

*Compressed gases.* High-pressure compressed gas cylinders used in the aircraft must have a current DOT stamp, and must be fitted with pressure regulators. All cylinders must be mounted with a positive forward stop; cylinders larger than 1-liter displacement must be held with a minimum of two aircraft-rated cylinder band clamps. Cylinder clamps can be obtained from several online sites, some of which are listed below.

[www.clampco.com](http://www.clampco.com/) – a wide variety of T-bolt and quick-release clamps.

[www.avoxsys.com](http://www.avoxsys.com/) – 800644, 803272 series cylinder band clamp bracket assemblies (for ca. 30 ft3 and larger cylinders).

[www.mhoxygen.com](http://www.mhoxygen.com/index.phtml?nav_id=28&product_id=300) - brackets and bands for smaller cylinders.

Please remember that cylinder clamp tensioning screws must be secured with safety wire or tie-wraps to prevent loosening under vibration. Hose clamps are not acceptable for securing compressed gas bottles.

Use of small-volume aluminum or composite cylinders on the aircraft can provide substantial weight savings over larger aluminum or steel cylinders. Aluminum medical oxygen cylinders (e.g., [Cramer-Decker Inc.](http://www.cramerdeckermedical.com/) or [Mada Medical](http://www.madamedical.com)) are inexpensive, very clean, and can be refilled for a period of 5 years beyond their latest hydrostatic test date. Composite-wrapped cylinders from [Luxfer Composites](http://www.luxfercylinders.com/products/medical/productrange/composite.shtml) are lighter than aluminum and are now quite inexpensive, ca. $150 per cylinder, and easily obtained. Note that aluminum and carbon-fiber-wrapped aluminum cylinders are DOT-rated for 5 years for refills; fiberglass- and Kevlar-wrapped cylinders can only be refilled for 3 years beyond their latest test date.

Compressed gas cylinders must be handled and stored according to safe practices at all times in the hangar, on the ramp, and on the aircraft. Please do not move cylinders with regulators attached unless properly restrained by a safety chain on a cylinder cart. Cylinder caps must be securely fastened before bringing pressurized cylinders up the aircraft stairs. Wheel chocks are required for utility and cylinder carts, especially those used on the ramp near the aircraft; small rubber chocks can be ordered from [Worden Safety Products.](http://www.chocks.com/index.php)

*Toxic/flammable gases.* Use of toxic and/or flammable gases requires a secondary containment and venting of cylinder and regulator, such that any leak is directed outside the aircraft fuselage. Containment vessels and vent ports should be clearly marked with standard safety placards. Gas volumes on board should be minimized, and bottles should not be serviced or refilled inside the aircraft; enclosure design should minimize the need to break the enclosure seals to refill or exchange the cylinder inside. The user must provide a calculation of aircraft cabin concentrations should the cylinder contents leak out with a concurrent failure of containment seals. Assume a cabin volume of 4260 ft3 = 1.21 x 105 liters. Please also provide the OSHA 8-hour permissible exposure level (PEL) and immediate danger to life and health (IDLH) limits for each toxic substance for reference. Two battery-powered alarms (e.g., the portable GasAlert line from [BW Technologies](http://store.jjstech.com/)) for each toxic or flammable gases are in most cases mandatory, and must be provided by the user, along with a tutorial for the AOC personnel on their use.

*Liquids.* Liquids must be in spill-proof containers with lids, and should be surrounded by a secondary means of containment should the reservoir or associated fittings develop a leak. Lining the inside of the containment vessel with non-flammable absorbent pads for hazmat (e.g., from [VWR](http://www.vwrsp.com)) is highly recommended. The containers must be labeled with standard safety placards, and their contents (and pH, for aqueous solutions) clearly marked. Procedures for draining or filling of liquids in installed scientific equipment should be clearly documented and provided to AOC for their approval via the CCT process. Spill kits and personal protective equipment specific to the liquids in question must be located convenient to the liquid reservoir, and instrument operators trained in their proper use. Liquid tubing routing and connections must be of high quality; good strain-relief of neatly bundled tubing runs and reliable, leak-free fittings are expected throughout.

*Radioactive materials.* The use of generally licensed ionizing devices has been permitted on a case-by-case basis. Prior installations have used 210Po (alpha emitter, half-life of 138.4 days) for mass spectrometer ion sources, 63Ni (beta emitter, half-life of 100 yrs) for GC detectors, and 85Kr (beta emitter, half-life of 10.7 yrs) for DMA columns. Please notify the [AIC](mailto:carsten.warneke@noaa.gov) if your instrument requires the use of any radioactive source, either installed on the aircraft or as support equipment on the ground.

#### Fire suppression/detection in pods. The AOC is continually reassessing its requirements in this regard; at present, active fire suppression in each pod is required. Since 2004 this has consisted of fused pyrotechnic canisters using a dry chemical extinguishing agent installed in each pod; details of the canisters can be found at [www.pyrogen.com](http://www.pyrogen.com/) or by contacting the [AIC](mailto:carsten.warneke@noaa.gov). It is possible that more extensive pod fire detection systems will be required in the future.

# Sampling inlets and probes

Design and construction of chemical and aerosol sampling inlets and probes, as well as optical ports and radiometer collector housings, must be approved by AOC personnel in advance of installation. For instruments installed in the fuselage, window plate blanks are provided and can be machined to accept a variety of inlet designs. For those sharing a common inlet, consider including isolation valves to take individual instruments off-line while minimizing the effects on other instruments. Existing, approved instrument inlets have standardized on either a sideways-facing inlet (using 4130 steel streamline tubing extrusion; part no. SL33-14-4, [Wicks Aircraft Supply](http://www.wicksaircraft.com/)) or a rearward-facing inlet. Flow tests show that an inlet 14” long will always be outside of the aircraft fuselage boundary layer during straight and level flight; inlets may be substantially shorter if they are located forward along the fuselage. Drawings of standard, approved inlet designs can be found on the CSD integration [web site](http://esrl.noaa.gov/csd/groups/csd7/measurements/2013senex/P3/integration/). Please contact the [AIC](mailto:carsten.warneke@noaa.gov) for if you have a question about new inlet designs.

### Pumps and exhaust

Continuous exhaust flows may not be vented through window plates upstream of any other instrument sampling locations along the fuselage. Appropriately sized PFA Teflon lines connected to separate nadir dump ports in the lower instrument port, forward (LIPF, informally known as the “pump bay”), must be used for continuous exhaust flows. Vent ports for non-continuous, or emergency, exhausts (LN2 dewar venting, containment vessel dumps, etc.) may be acceptable upstream of other sampling inlet locations on a case-by-case basis.

Liquid or condensing gases should never be directed into these exhaust lines. If condensation occurs, the investigator will be asked to purge the liquids from these tubing runs, or replace the tubing, at the end of the project. Further, coalescing filters on the exhaust ports of all oil-sealed pumps are mandatory, to minimize contamination over time of the exhaust tubing installed in the aircraft.

At present, two Busch pumps will be installed in the pump bay. Requests for additional LIPF pump installations, or availability of any excess pumping capacity, should be coordinated with the [AIC](mailto:carsten.warneke@noaa.gov).

### Installation schedule

Installation begins approximately 8 weeks before the transit/science flights begin, subject to aircraft availability. New installations will be generally scheduled for early in the integration period. Please arrive with ALL necessary sheet metal brackets, hardware, mounting plates, safety covers, compressed gas cylinder mounts, and machining work already finished. The AOC sheet metal shop is excellent but is easily swamped by multiple last-minute requests for their services. Please register all your requests for sheet-metal support on the P-3 Installation Worksheet (Appendix 1) well in advance of arriving in Tampa.

### Equipment inspection and acceptance

At present, a Configuration Control Team (CCT) of AOC engineers and technicians determines whether each instrument is acceptable for flight. AOC assigns smaller teams of engineers and techs to each instrument, and these teams are responsible for working with the instrument PIs to complete a standard information checklist either prior to or during integration. The checklists help identify safety-of-flight questions or instrument operation issues needing further clarification. Once completed, the full CCT team will meet to either sign off on, or require changes to, each instrument prior to the first project flight.

This final CCT decision can occur only after the instrument in question has been fully installed and can be inspected in its final configuration. However, much of the necessary groundwork can be accomplished well in advance of integration into the aircraft. For the most part, completion of the P-3 Installation Worksheet (Appendix 1) should provide the information needed by AOC staff to evaluate the instruments being installed; the remainder of the CCT task is to verify safe installation procedures have been followed. The CCT information checklist illustrates what they will be looking for in a flight-ready installation.

**Working at MacDill AFB, Tampa, FL**

• *Tool control*: Flight-critical wiring, control cables, hydraulic lines, and actuators run overhead, along the sidewalls, and underneath the floor inside the P-3 fuselage; these systems can be easily damaged by foreign objects brought on board during equipment installation or operation. As a result, tool control is strictly implemented on the P-3 as a flight safety measure. “Tool control” extends to any small parts – nuts, washers, hardware, pencils, jewelry, coins, etc. – taken on board the aircraft. If you drop something, you are responsible for immediately picking it up before continuing with other tasks. If you can’t locate a dropped item, please call it to the attention of the AOC techs, they will assist in locating it with you.

If you plan to bring any of your own tools on board the aircraft, please provide a complete written list to the lead AOC tech before bringing them on board, and check the tools against this list before departing each day.

#### • Hygiene & footwear: Work in and around the aircraft can entail long, hot hours in a poorly ventilated space in close proximity to other scientists, engineers, and aircrew. Attention to personal hygiene is expected and very much appreciated by all your colleagues. High heels, open-toed sandals, or Crocs are not allowed in the hangar or around the aircraft.

• *Documentation:* It is good practice to bring your own copies of MSDSs, structural analyses, documentation, wiring schemes, etc., that are relevant to your installation. While you may have already sent copies in to AOC, substantial time can sometimes be saved if you can produce a backup copy when needed.

### • *Weather*. Please anticipate all-weather operation with regard to chemical sampling inlets and preflight/postflight operations. Plan to bring the necessary supplies to protect inlet lines and equipment from rain (and dust storms, snow, de-icing fluid, etc.). Temporary external covers must be clearly marked with “remove before flight” flags (available from [Wick's Aircraft](http://www.wicksaircraft.com)), and be able to withstand high winds on the ramp without departing from the aircraft. Finally, exhaust and fumes from refueling trucks and the aircraft power cart can be substantial at times during preflight.

• *Equipment installation, servicing, and removal from aircraft.* All installation work will be performed at AOC in Tampa, FL. Removal of individual components after installation for servicing and repair is always permitted during the project, after notifying AOC staff and logging payload weight changes. Once installed, removal of major components or whole instruments from the fuselage is typically not done in the field. De-integration of the whole payload at the end of the project will also be performed at AOC in Tampa, FL or at another facility designated by AOC.

**Reporting data after a flight**

Within 24 hours of a flight, preliminary P-3 flight level data (including aircraft position, meteorological information, and miscellaneous data) will be available for download on the CSD project [web site](http://esrl.noaa.gov/csd/groups/csd7/measurements/2013senex/P3/integration/). Whenever possible, PIs are also requested to provide quick-look data within 24 hours of a research flight. 1-Hz instrumental data should be on the 1-Hz aircraft time base, which is best determined by matching the variability in each data stream to that seen in the DewPtTempTDL data, in the flight level data folder on the project [web site](http://esrl.noaa.gov/csd/groups/csd7/measurements/2013senex/P3/integration/). The P-3 community has adopted the ICARTT format for data files, including the quick-look files posted directly after a flight. For answers to questions on data time alignment, upload procedures, and the ICARTT format, please contact [Ken Aikin](mailto:Kenneth.C.Aikin@noaa.gov), the CSD P-3 data manager.

**Information available on CSD web site**

Finally, please familiarize yourself with the CSD WP-3D integration [web site](http://esrl.noaa.gov/csd/groups/csd7/measurements/2013senex/P3/integration/), which has a great deal of additional information regarding fuselage layout, electrical wiring diagrams, engineering drawings, rack weight and overturning moment worksheets, and other details needed to work on these NOAA aircraft.

**Needed Documentation for Instrument Descriptions**

For the integration of each instrument some information is necessary Please provide the following three documents: 1) General P3 installation worksheet, 2) rack weight and balance Excel form and 3) 2-page scientific instrument description. These forms are due to the [AIC](mailto:carsten.warneke@noaa.gov) by October 1, 2012 for the SENEX 2013 project.

I. General information:

Please fill out the general P3 installation worksheet, available on the [website](mailto:http://esrl.noaa.gov/csd/groups/csd7/measurements/2013senex/P3/integration/), for your specific instrument.

II. 2-page scientific description

Please provide a 2-page scientific description of your instrument for the scientists in SENEX2013 that could be used as a starting point for the instrumental section in a publication about SENEX2013. This should include information such as:

* instrument name
* species measured
* method used possibly including instrument schematics and pictures
* uncertainty, detection limit and time resolution
* special comments for SENEX2013
* references for the instrument description

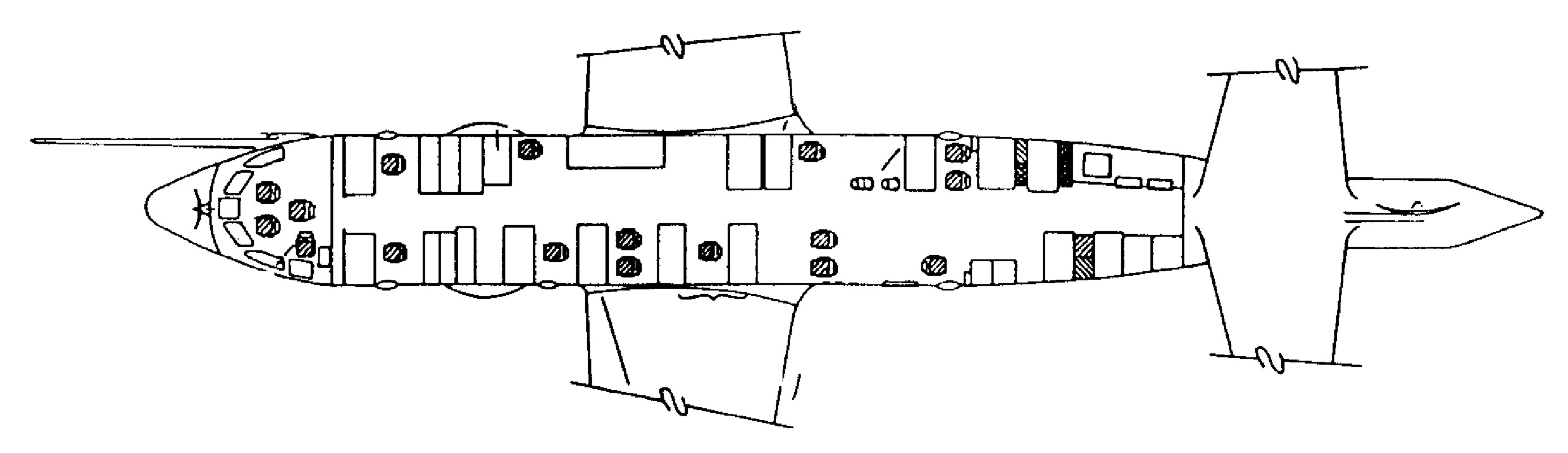
III. Weight and balance worksheet

Please fill out the weight and balance sheet, available on the [website](mailto:http://esrl.noaa.gov/csd/groups/csd7/measurements/2013senex/P3/integration/), for your specific instrument location.

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Station** | **Max weight (lbs)** | | | **Mounting location** | | | **CG location** | | | **Overturning moment (in-lbs)** | | |
| *Inboard* | *Outboard* | *Total* | *Forward* | *Aft* | *Delta* | *Flight station* | *W.L.* | *Height* | *Max inboard* | *Max outboard* | *Total* |
| FD | 312.5 | 312.5 | **625.0** | 300.1 | 319.1 | 19.0 | 311.85 | 155.5 | 32 | 10000 | 10000 | 20000 |
| C3X | 350.0 | 350.0 | **700.0** | 429.0 | 465.0 | 27.0 | 453.9 | 151.5 | 28.0 | 9800 | 9800 | 19600 |
| Sta. 2 | 250.0 | 250.0 | **500.0** | 459.0 | 486.0 | 27.0 | 477.19 | 150.3 | 26.8 | 6700 | 6700 | 13400 |
| Sta. 3 | 272.0 | 385.0 | **657.0** | 526.0 | 553.0 | 27.0 | 541.2 (±) | 154.4 | 30.9 | 8405 | 11396 | 19801 |
|  |  |  |  |  |  |  | 543.0 (0) | 153.1 | 29.6 |  |  |  |
| Sta. 4 | 332.0 | 291.0 | **623.0** | 604.9 | 628.1 | 23.2 | 619.9 (±) | 151.8 | 28.3 | 9396 | 8264 | 17660 |
|  |  |  |  |  |  |  | 620.0 (0) | 151.9 | 28.4 |  |  |  |
| N1/N2 | 504.0 | 430.0 | **934.0** | 675.0 | 700.0 | 25.0 | 685.8 (±) | 161.1 | 37.6 | 18950 | 13287 | 32237 |
|  |  |  |  |  |  |  | 686.1 (0) | 154.4 | 30.9 |  |  |  |
| Sta. 5 | 350.0 | 350.0 | **700.0** | 710.6 | 737.6 | 27.0 | 727.1 | 151.5 | 28.0 | 9800 | 9800 | 19600 |
| Sta. 6 | 262.5 | 262.5 | **525.0** | 776.1 | 799.9 | 23.8 | 792.7 | 153.5 | 30.0 | 7875 | 7875 | 15750 |
| Sta. 7 | 262.5 | 262.5 | **525.0** | 841.1 | 864.9 | 23.8 | 857.6 | 153.5 | 30.0 | 7875 | 7875 | 15750 |
| Sta. 8\* |  |  |  |  |  |  |  |  |  |  |  |  |
| Dual pass.\* |  |  |  |  |  |  |  |  |  |  |  |  |
| J cab\* |  |  |  |  |  |  |  |  |  |  |  |  |

From a document signed by J. Zysko, 27 April 81

\* These stations are approved for specific CSD installations only. Please contact the [AIC](mailto:carsten.warneke@noaa.gov) for details.



B cab

LIPF

Sta. 4

NAV

Sta. 15

Sta. 5

Sta. 6

Sta. 7

J cab

Sta. 8

Dual pass.

Sta. 12

Sta. 3

Sta. 2

FD

Sta. C3X

Sta. 16