| MIXED GAS NAME | SYMBOL | CODE |
|---|---|---|
| 134A)/44%PENTAFLUOROETHANE (FREON-125)/ ETHANE,1,1,1-TRIFLUORO-(HFC-143a) | | |
| 30%PROPANE/BUTANE | 30%C3H8/C4H10 | 0885 |
| .01%PHOSPHINE/ARGON | .01%PH3/Ar | 0886 |
| .1%PHOSPHINE/ARGON | .1%PH3/Ar | 0887 |
| .1%DIBORANE/ARGON | .1%B2H6/Ar | 0888 |
| .5%PHOSPHINE/HELIUM | .5%PH3/He | 0889 |
| 5.5%ARSENIC TRICHLORIDE/HYDROGEN | 5.5%AsCl3/H2 | 0890 |
| 17.4%GERMANIUM TETRACHLORIDE/HYDROGEN | 17.4%GeCl4/H2 | 0891 |
| 32%SILICON TETRACHLORIDE/HYDROGEN | 32%SiCl4/O2 | 0892 |
| 18.4%PHOSPHORUS OXYCHLORIDE/OXYGEN | 18.4%POCl3/O2 | 0893 |
| 13%DISELENIUM DICHLORIDE/HYDROGEN | 13%Se2Cl2/H2 | 0894 |
| 40%GERMANE/NITROGEN | 40%GeH4/N2 | 0895 |
| 30%PHOSPHINE/SILANE | 30%PH3/SiH4 | 0896 |
| 2.7%ETHYLENE/HELIUM | 2.7%C2H4/He | 0897 |
| 1%GERMANE/HYDROGEN | 1%GeH4/H2 | 0898 |
| 1%METHYLSILANE (MONO)/HYDROGEN | 1%CH6Si/H2 | 0899 |
| .48%NITROGEN TRIFLUORIDE/NITROGEN | .48%NF3/N2 | 0900 |
| 7%OZONE/OXYGEN | 7%O3/O2 | 0901 |
| .2%HYDROGEN SULFIDE/NITROGEN | .2%H2S/N2 | 0902 |
| 2%HYDROGEN SULFIDE/NITROGEN | 2%H2S/N2 | 0903 |
| 2%NITROGEN DIOXIDE/NITROGEN | 2%NO2/N2 | 0904 |
| .4%CHLORINE/NITROGEN | .4%Cl2/N2 | 0905 |
| 4.6%SULFUR DIOXIDE/NITROGEN | 4.6%SO2/N2 | 0906 |
| 10%ARSINE/NITROGEN | 10%AsH3/N2 | 0907 |
| 20%DIBORANE/HELIUM | 20%B2H6/He | 0908 |

## 10 Mixed Gas Table Sorted by Percentage

### Table 5 Mixed Gases Sorted by Percentage

| MIXED GAS NAME | SYMBOL | CODE |
|---|---|---|
| .01%DIBORANE/HYDROGEN | .01%B2H6/H2 | 0547 |
| .01%PHOSPHINE/ARGON | .01%PH3/Ar | 0886 |
| .01%SILANE/HYDROGEN | .01%SiH4/H2 | 0548 |
| .02%CARBON MONOXIDE/NITROGEN | .02%CO/N2 | 0784 |
| .05%DIBORANE/HYDROGEN | .05%B2H6/H2 | 0690 |
| .06%ARSINE/HYDROGEN | .06%AsH3/H2 | 0708 |
| .1%CARBON MONOXIDE/NITROGEN | .1%CO/N2 | 0786 |
| .1%DIBORANE/ARGON | .1%B2H6/Ar | 0888 |
| .1%HYDROGEN CHLORIDE/NITROGEN | .1%HCl/N2 | 0790 |
| .1%HYDROGEN/.25%CARBON MONOXIDE/1%OXYGEN/NITROGEN | .1%H2/.25%CO/1%O2/N2 | 0879 |
| .1%NITROGEN DIOXIDE/AIR | .1%NO2/Air | 0791 |
| .1%NITROGEN DIOXIDE/NITROGEN | .1%NO2/N2 | 0792 |
| .1%PHOSPHINE/ARGON | .1%PH3/Ar | 0887 |
| .1%PHOSPHINE/HYDROGEN | .1%PH3/H2 | 0793 |

| *MIXED GAS NAME* | *SYMBOL* | *CODE* |
|---|---|---|
| .1%PHOSPHINE/NITROGEN | .1%PH3/N2 | 0789 |
| .2%HYDROGEN SULFIDE/NITROGEN | .2%H2S/N2 | 0902 |
| .2%SULFUR DIOXIDE/AIR | .2%SO2/Air | 0794 |
| .25%CARBON MONOXIDE/.1%HYDROGEN/1%OXYGEN/NITROGEN | .25%CO/.1%H2/1%O2/N2 | 0795 |
| .25%DIBORANE/HYDROGEN | .25%B2H6/H2 | 0796 |
| .25%OXYGEN/.5%HYDROGEN/1.5%CA RBON MONOXIDE/NITROGEN | .25%O2/.5%H2/1.5%CO/N2 | 0797 |
| .3%PHOSPHINE/SILANE | .3%PH3/SiH4 | 0660 |
| .4%CHLORINE/NITROGEN | .4%Cl2/N2 | 0905 |
| .4%HYDROGEN CHLORIDE/AIR | .4%HCl/Air | 0798 |
| .48%NITROGEN TRIFLUORIDE/NITROGEN | .48%NF3/N2 | 0900 |
| .5%ARSINE/SILANE | .5%AsH3/SiH4 | 0799 |
| .5%BORON TRICHLORIDE/HYDROGEN | .5%BCI3/H2 | 0655 |
| .5%DIBORANE/ARGON | .5%B2H6/Ar | 0549 |
| .5%PHOSPHINE/HELIUM | .5%PH3/He | 0889 |
| .5%PHOSPHINE/HYDROGEN | .5%PH3/H2 | 0656 |
| .5%PHOSPHINE/NITROGEN | .5%PH3/N2 | 0550 |
| .5%SILANE/HYDROGEN | .5%SiH4/H2 | 0551 |
| .7%ARSINE/HELIUM | .7%AsH3/He | 0721 |
| .7%ARSINE/HYDROGEN | .7%AsH3/H2 | 0673 |
| .7%GERMANIUM/HYDROGEN | .7%GeH4/H2 | 0771 |
| .8%ARSINE/HYDROGEN | .8%AsH3/H2 | 0741 |
| .8%CO/.8%O2/20%CO2/32%N2/H2 | SELOX GAS MIX | 0774 |
| .8%DIBORANE/HYDROGEN | .8%B2H6/H2 | 0743 |
| .8%DIBORANE/NITROGEN | .8%B2H6/N2 | 0662 |
| .8%GERMANIUM TETRAFLUORIDE/HYDROGEN | .8%GeF4/H2 | 0742 |
| .8%PHOSPHINE/DISILANE | .8%PH3/Si2H6 | 0681 |
| .8%PHOSPHINE/HELIUM | .8%PH3/He | 0675 |
| .8%PHOSPHINE/HYDROGEN | .8%PH3/H2 | 0707 |
| .8%PHOSPHINE/NITROGEN | .8%PH3/N2 | 0552 |
| .8%PHOSPHINE/SILANE | .8%PH3/SiH4 | 0553 |
| .9%ARSINE/HYDROGEN | .9%AsH3/H2 | 0554 |
| 1%ACETYLENE/ETHYLENE | 1%C2H2/C2H4 | 0772 |
| 1%ARSINE/HYDROGEN | 1%AsH3/H2 | 0724 |
| 1%ARSINE/NITROGEN | 1%AsH3/N2 | 0555 |
| 1%ARSINE/SILANE | 1%AsH3/SiH4 | 0556 |
| 1%BORON TRICHLORIDE/HYDROGEN | 1%BCI3/H2 | 0559 |
| 1%BORON TRICHLORIDE/NITROGEN | 1%BCI3/N2 | 0560 |
| 1%BUTADIENE/BUTENE | 1%C4H6-e)/C4H8-i) | 0750 |
| 1%CARBON DIOXIDE/NITROGEN | 1%CO2/N2 | 0800 |
| 1%CARBON MONOXIDE/19% NITROGEN/30%OXYGEN/CARBON DIOXIDE | 1%CO/19%N2/30%O2/CO2 | 0801 |
| 1%CARBON MONOXIDE/AIR | 1%CO/Air | 0802 |
| 1%CARBON MONOXIDE/CARBON DIOXIDE | 1%CO/CO2 | 0803 |
| 1%CHLORINE/NITROGEN | 1%Cl2/N2 | 0804 |
| 1%DIBORANE/ARGON | 1%B2H6/Ar | 0805 |

| *MIXED GAS NAME* | *SYMBOL* | *CODE* |
|---|---|---|
| 1%DIBORANE/HYDROGEN | 1%B2H6/H2 | 0557 |
| 1%DIBORANE/NITROGEN | 1%B2H6/N2 | 0558 |
| 1%FLUORINE/NEON | 1%F2/Ne | 0733 |
| 1%GERMANE/HYDROGEN | 1%GeH4/H2 | 0898 |
| 1%GERMANE/NITROGEN | 1%GeH4/N2 | 0658 |
| 1%HYDROGEN SELENIDE/HYDROGEN | 1%H2Se/H2 | 0645 |
| 1%HYDROGEN SULFIDE/HYDROGEN | 1%H2S/H2 | 0644 |
| 1%HYDROGEN SULFIDE/NITROGEN | 1%H2S/N2 | 0806 |
| 1%HYDROGEN/NITROGEN | 1%H2/N2 | 0561 |
| 1%METHANE/49.5%CARBON DIOXIDE/ARGON | 1%CH4/49.5%CO2/Ar | 0807 |
| 1%METHYLSILANE (MONO)/HYDROGEN | 1%CH6Si/H2 | 0899 |
| 1%NITROGEN DIOXIDE/AIR | 1%NO2/Air | 0808 |
| 1%NITROGEN DIOXIDE/NITROGEN | 1%NO2/N2 | 0781 |
| 1%NITROGEN/HYDROGEN | 1%N2/H2 | 0871 |
| 1%OXYGEN/NITROGEN | 1%O2/N2 | 0562 |
| 1%PHOSPHINE/ARGON | 1%PH3/Ar | 0537 |
| 1%PHOSPHINE/HELIUM | 1%PH3/He | 0546 |
| 1%PHOSPHINE/HYDROGEN | 1%PH3/H2 | 0563 |
| 1%PHOSPHINE/NITROGEN | 1%PH3/N2 | 0514 |
| 1%PHOSPHINE/SILANE | 1%PH3/SiH4 | 0531 |
| 1%SILANE/DIBORANE | 1%SiH4/B2H6 | 0684 |
| 1%SILANE/HELIUM | 1%SiH4/He | 0745 |
| 1%SULFUR DIOXIDE/ARGON | 1%SO2/Ar | 0809 |
| 1%SULFUR DIOXIDE/NITROGEN | 1%SO2/N2 | 0782 |
| 1%TRIMETHYLBORATE(TMB)/HYDROGEN | 1%(CH3O)3B/H2 | 0526 |
| 1.5%ARSINE/HYDROGEN | 1.5%AsH3/H2 | 0564 |
| 1.5%GERMANE/HYDROGEN | 1.5%GeH4/H2 | 0775 |
| 1.5%PHOSPHINE/SILANE | 1.5%PH3/SiH4 | 0533 |
| 1.5%SILANE/ARGON | 1.5%SiH4/Ar | 0810 |
| 1.6%PHOSPHINE/21%SILANE/ARGON | 1.6%PH3/21%SiH4/Ar | 0515 |
| 1.65%ACETYLENE/70%ETHYLENE/NITROGEN | 1.65%C2H2/70%C2H4/N2 | 0873 |
| 1.8%SILANE/NITROGEN | 1.8%SiH4/N2 | 0811 |
| 1.9%SILANE/NITROGEN | 1.9%SiH4/N2 | 0812 |
| 10%AMMONIA/NITROGEN | 10%NH3/N2 | 0668 |
| 10%ARSINE/HYDROGEN | 10%AsH3/H2 | 0504 |
| 10%ARSINE/NITROGEN | 10%AsH3/N2 | 0907 |
| 10%CARBON DIOXIDE/10%OXYGEN/NITROGEN | 10%CO2/10%O2/N2 | 0735 |
| 10%CARBON DIOXIDE/ARGON | 10%CO2/Ar | 0813 |
| 10%CARBON DIOXIDE/NITROGEN | 10%CO2/N2 | 0783 |
| 10%CARBON MONOXIDE/AIR | 10%CO/Air | 0730 |
| 10%CARBON MONOXIDE/CARBON DIOXIDE | 10%CO/CO2 | 0729 |
| 10%CYCLOPROPANE/HELIUM | 10%C3H6-a)/He | 0716 |
| 10%DIBORANE/ARGON | 10%B2H6/Ar | 0881 |
| 10%DIBORANE/HYDROGEN | 10%B2H6/H2 | 0701 |
| 10%DIBORANE/NITROGEN | 10%B2H6/N2 | 0666 |

| *MIXED GAS NAME* | *SYMBOL* | *CODE* |
|---|---|---|
| 10%DISILANE/ARGON | 10%Si2H6/Ar | 0670 |
| 10%DISILANE/HELIUM | 10%Si2H6/He | 0647 |
| 10%DISILANE/HYDROGEN | 10%Si2H6/H2 | 0731 |
| 10%ETHYLENE/HELIUM | 10%C2H4/He | 0718 |
| 10%FLUORINE/ARGON | 10%F2/Ar | 0754 |
| 10%FLUORINE/HELIUM | 10%F2/He | 0566 |
| 10%FLUORINE/NITROGEN | 10%F2/N2 | 0759 |
| 10%FLUORINE/OXYGEN | 10%F2/O2 | 0814 |
| 10%GERMANE/ARGON | 10%GeH4/Ar | 0698 |
| 10%GERMANE/HELIUM | 10%GeH4/He | 0704 |
| 10%GERMANE/HYDROGEN | 10%GeH4/H2 | 0509 |
| 10%HELIUM/HYDROGEN | 10%He/H2 | 0749 |
| 10%HYDROGEN SELENIDE/HYDROGEN | 10%H2Se/H2 | 0511 |
| 10%HYDROGEN/NITROGEN | 10%H2/N2 | 0532 |
| 10%METHANE/ARGON | 10%CH4/Ar | 0710 |
| 10%METHANE/HELIUM | 10%CH4/He | 0744 |
| 10%METHANE/HYDROGEN | 10%CH4/H2 | 0815 |
| 10%METHYLSILANE/HYDROGEN | 10%CH6Si/H2 | 0689 |
| 10%NITROGEN TRIFLUORIDE/OXYGEN | 10%NF3/O2 | 0570 |
| 10%NITROGEN/ARGON | 10%N2/Ar | 0576 |
| 10%OXYGEN/30%CARBON DIOXIDE/ARGON | 10%O2/30%CO2/Ar | 0816 |
| 10%OXYGEN/HELIUM | 10%O2/He | 0649 |
| 10%OZONE/NITROGEN | 10%O3/N2 | 0817 |
| 10%OZONE/OXYGEN | 10%O3/O2 | 0571 |
| 10%PHOSPHINE/ARGON | 10%PH3/Ar | 0538 |
| 10%PHOSPHINE/HELIUM | 10%PH3/He | 0674 |
| 10%PHOSPHINE/HYDROGEN | 10%PH3/H2 | 0516 |
| 10%PHOSPHINE/NITROGEN | 10%PH3/N2 | 0527 |
| 10%PHOSPHINE/SILANE | 10%PH3/SiH4 | 0572 |
| 10%SILANE/ARGON | 10%SiH4/Ar | 0565 |
| 10%SILANE/HELIUM | 10%SiH4/He | 0573 |
| 10%SILANE/HYDROGEN | 10%SiH4/H2 | 0575 |
| 10%SILANE/NITROGEN | 10%SiH4/N2 | 0646 |
| 10%SULFUR DIOXIDE/NITROGEN | 10%SO2/N2 | 0818 |
| 10%TRIMETHYSILANE/HYDROGEN | 10%(CH3)3SiH/H2 | 0739 |
| 10%WATER VAPOR/NITROGEN | 10%H2O/N2 | 0568 |
| 11%OZONE/OXYGEN | 11%O3/O2 | 0868 |
| 12%HYDROGEN/NITROGEN | 12%H2/N2 | 0819 |
| 12%OZONE/OXYGEN | 12%O3/O2 | 0651 |
| 13%DISELENIUM DICHLORIDE/HYDROGEN | 13%Se2Cl2/H2 | 0894 |
| 13%HYDROGEN CHLORIDE/1.32%XE NON/NEON | 13%HCI/1.32%Xe/Ne | 0512 |
| 13%HYDROGEN/NITROGEN | 13%H2/N2 | 0643 |
| 13%TRICHLOROSILANE/HYDROGEN | 13%SiHCI3/H2 | 0682 |
| 15%ARGON/PHOSPHINE | 15%Ar/PH3 | 0578 |
| 15%ARSINE/HYDROGEN | 15%AsH3/H2 | 0579 |

| *MIXED GAS NAME* | *SYMBOL* | *CODE* |
|---|---|---|
| 15%CARBON DIOXIDE/NITROGEN | 15%CO2/N2 | 0778 |
| 15%DIBORANE/ARGON | 15%B2H6/Ar | 0697 |
| 15%DIBORANE/HYDROGEN | 15%B2H6/H2 | 0820 |
| 15%DIBORANE/NITROGEN | 15%B2H6/N2 | 0580 |
| 15%GERMANIUM TETRACHLORIDE/OXYGEN | 15%GeCl4/O2 | 0787 |
| 15%HYDROGEN/ARGON | 15%H2/Ar | 0694 |
| 15%HYDROGEN/NITROGEN | 15%H2/N2 | 0545 |
| 15%NITRIC OXIDE/NITROGEN | 15%NO/N2 | 0652 |
| 15%OZONE/OXYGEN | 15%O3/O2 | 0641 |
| 15%PHOSPHINE/15%SILANE/NITROGEN | 15%PH3/15%SiH4/N2 | 0581 |
| 15%PHOSPHINE/ARGON | 15%PH3/Ar | 0582 |
| 15%PHOSPHINE/HYDROGEN | 15%PH3/H2 | 0583 |
| 15%PHOSPHINE/NITROGEN | 15%PH3/N2 | 0500 |
| 15%PHOSPHINE/SILANE | 15%PH3/SiH4 | 0584 |
| 15%SILANE/ARGON | 15%SiH4/Ar | 0821 |
| 15%SILANE/HELIUM | 15%SiH4/He | 0864 |
| 15%SILANE/NITROGEN | 15%SiH4/N2 | 0519 |
| 16%CARBON DIOXIDE/NITROGEN | 16%CO2/N2 | 0543 |
| 17%OXYGEN/CARBON TETRAFLUORIDE(FREON-14) | 17%O2/CF4 | 0585 |
| 17.4%GERMANIUM TETRACHLORIDE/HYDROGEN | 17.4%GeCl4/H2 | 0891 |
| 18.4%PHOSPHORUS OXYCHLORIDE/OXYGEN | 18.4%POCl3/O2 | 0893 |
| 2%ARSINE/HYDROGEN | 2%AsH3/H2 | 0703 |
| 2%ARSINE/NITROGEN | 2%AsH3/N2 | 0586 |
| 2%ARSINE/SILANE | 2%AsH3/SiH4 | 0663 |
| 2%DIBORANE/ARGON | 2%B2H6/Ar | 0587 |
| 2%DIBORANE/NITROGEN | 2%B2H6/N2 | 0695 |
| 2%DISILANE/HELIUM | 2%Si2H6/He | 0764 |
| 2%GERMANE/ARGON | 2%GeH4/Ar | 0740 |
| 2%HYDROGEN SULFIDE/NITROGEN | 2%H2S/N2 | 0903 |
| 2%HYDROGEN/NITROGEN | 2%H2/N2 | 0588 |
| 2%METHYSILANE/HYDROGEN | 2%CH6Si/H2 | 0717 |
| 2%NITRIC OXIDE/NITROGEN | 2%NO/N2 | 0822 |
| 2%NITROGEN DIOXIDE/NITROGEN | 2%NO2/N2 | 0904 |
| 2%NITROGEN/3%CARBON MONOXIDE/17%CARBON DIOXIDE/HYDROGEN | 2%N2/3%CO/17%CO2/H2 | 0788 |
| 2%OXYGEN/ARGON | 2%O2/Ar | 0863 |
| 2%OZONE/OXYGEN | 2%O3/O2 | 0569 |
| 2%PHOSPHINE/ARGON | 2%PH3/Ar | 0539 |
| 2%PHOSPHINE/NITROGEN | 2%PH3/N2 | 0640 |
| 2%PHOSPHINE/SILANE | 2%PH3/SiH4 | 0696 |
| 2%SILANE/ARGON | 2%SiH4/Ar | 0823 |
| 2%SILANE/HELIUM | 2%SiH4/He | 0589 |
| 2%SILANE/HYDROGEN | 2%SiH4/H2 | 0544 |
| 2%SILANE/NITROGEN | 2%SiH4/N2 | 0653 |
| 2%SULFUR DIOXIDE/NITROGEN | 2%SO2/N2 | 0824 |

| *MIXED GAS NAME* | *SYMBOL* | *CODE* |
|---|---|---|
| 2%TRICHLOROETHANE/NITROGEN | 2%C2H3Cl3/N2 | 0506 |
| 2.5%DIBORANE/HYDROGEN | 2.5%B2H6/H2 | 0825 |
| 2.5%METHANE/AIR | 2.5%CH4/Air | 0826 |
| 2.5%OXYGEN/5%CARBON DIOXIDE/NITROGEN | 2.5%O2/5%CO2/N2 | 0866 |
| 2.7%ETHYLENE/HELIUM | 2.7%C2H4/He | 0897 |
| 20%ARGON/SILANE | 20%Ar/SiH4 | 0540 |
| 20%ARSINE/HYDROGEN | 20%AsH3/H2 | 0590 |
| 20%CARBON DIOXIDE/HYDROGEN | 20%CO2/H2 | 0507 |
| 20%CARBON TETRAFLUORIDE/NITROGEN | 20%CF4/N2 | 0728 |
| 20%DIBORANE/HELIUM | 20%B2H6/He | 0908 |
| 20%DIBORANE/SILANE | 20%B2H6/SiH4 | 0591 |
| 20%DISILANE/HELIUM | 20%Si2H6/He | 0648 |
| 20%DISILANE/HYDROGEN | 20%Si2H6/H2 | 0713 |
| 20%FLUORINE/HELIUM | 20%F2/He | 0677 |
| 20%FLUOROFORM/OXYGEN | 20%CF4/O2 | 0827 |
| 20%HELIUM/OXYGEN | 20%He/O2 | 0687 |
| 20%HYDROGEN/CARBON MONOXIDE | 20%H2/CO | 0592 |
| 20%NITROGEN/HYDROGEN | 20%N2/H2 | 0880 |
| 20%OXYGEN/ARGON | 20%O2/Ar | 0875 |
| 20%OXYGEN/CARBON TETRAFLUORIDE(FREON-14) | 20%O2/CF4 | 0513 |
| 20%OXYGEN/HELIUM | 20%O2/He | 0536 |
| 20%OXYGEN/NITROGEN | 20%O2/N2 | 0736 |
| 20%OZONE/NITROGEN | 20%O3/N2 | 0723 |
| 20%OZONE/OXYGEN | 20%O3/O2 | 0869 |
| 20%PHOSPHINE/HYDROGEN | 20%PH3/H2 | 0593 |
| 20%PHOSPHINE/NITROGEN | 20%PH3/N2 | 0767 |
| 20%PHOSPHINE/SILANE | 20%PH3/SiH4 | 0530 |
| 20%SILANE/ARGON | 20%SiH4/Ar | 0541 |
| 20%SILANE/HELIUM | 20%SiH4/He | 0529 |
| 20%SILANE/HYDROGEN | 20%SiH4/H2 | 0577 |
| 20%SILANE/NITROGEN | 20%SiH4/N2 | 0502 |
| 20%TRICHLOROSILANE/HYDROGEN | 20%SiHCI3/H2 | 0522 |
| 20%TRIMETHYLALUMINUM(TMAI)/HYDROGEN | 20%(CH3)3AI/H2 | 0525 |
| 21%OXYGEN/NITROGEN | 21%O2/N2 | 0594 |
| 21%SILANE/4%PHOSPHINE/ARGON | 21%SiH4/4%PH3/Ar | 0520 |
| 21.6%CARBON DIOXIDE/32.4%NITROGEN/HYDROGEN | 21.6%CO2/32.4%N2/H2 | 0882 |
| 22%OXYGEN/HELIUM | 22%O2/He | 0828 |
| 22%PHOSPHINE/SILANE | 22%PH3/SiH4 | 0678 |
| 25%AMMONIA/HYDROGEN | 25%NH3/H2 | 0638 |
| 25%CARBON MONOXIDE/HYDROGEN | 25%CO/H2 | 0829 |
| 25%FLUORINE/ARGON | 25%F2/Ar | 0755 |
| 25%FLUORINE/HELIUM | 25%F2/He | 0758 |
| 25%FLUORINE/NITROGEN | 25%F2/N2 | 0746 |
| 25%HELIUM/ARGON | 25%He/Ar | 0737 |
| 25%HEXAFLUOROETHANE/OXYGEN | 25%C2F6/O2 | 0770 |

| *MIXED GAS NAME* | *SYMBOL* | *CODE* |
|---|---|---|
| 25%PHOSPHINE/SILANE | 25%PH3/SiH4 | 0517 |
| 25%PROPANE/PROPYLENE | 25%C3H8/C3H6 | 0830 |
| 25%TRICHLOROSILANE/HYDROGEN | 25%SiHCI3/H2 | 0680 |
| 3%AMMONIA/NITROGEN | 3%NH3/N2 | 0831 |
| 3%ARSINE/ARGON | 3%AsH3/Ar | 0688 |
| 3%ARSINE/HYDROGEN | 3%AsH3/H2 | 0665 |
| 3%BORON TRICHLORIDE/HYDROGEN | 3%BCl3/H2 | 0832 |
| 3%DIBORANE/5%SILANE/NITROGEN | 3%B2H6/5%SiH4/N2 | 0659 |
| 3%DIBORANE/HYDROGEN | 3%B2H6/H2 | 0657 |
| 3%DIBORANE/NITROGEN | 3%B2H6/N2 | 0595 |
| 3%ETHYLENE/HELIUM | 3%C2H4/He | 0878 |
| 3%HYDROGEN/ARGON | 3%H2/Ar | 0833 |
| 3%HYDROGEN/HELIUM | 3%H2/He | 0596 |
| 3%HYDROGEN/NITROGEN | 3%H2/N2 | 0597 |
| 3%NITROGEN/HYDROGEN | 3%N2/H2 | 0672 |
| 3%OXYGEN/HELIUM | 3%O2/He | 0598 |
| 3%OZONE/AIR | 3%O3/Air | 0599 |
| 3%PHOSPHINE/5%SILANE/NIT ROGEN | 3%PH3/5%SiH4/N2 | 0671 |
| 3%PHOSPHINE/ARGON | 3%PH3/Ar | 0534 |
| 3%PHOSPHINE/HELIUM | 3%PH3/He | 0834 |
| 3%PHOSPHINE/NITROGEN | 3%PH3/N2 | 0600 |
| 3%PHOSPHINE/SILANE | 3%PH3/SiH4 | 0601 |
| 3%PROPANE/HYDROGEN | 3%C3H8/H2 | 0872 |
| 3%SILANE/HELIUM | 3%SiH4/He | 0602 |
| 3%SILANE/HYDROGEN | 3%SiH4/H2 | 0870 |
| 3.5%CARBON DIOXIDE/HELIUM | 3.5%CO2/He | 0835 |
| 3.5%HYDROGEN/NITROGEN | 3.5%H2/N2 | 0768 |
| 30% ISOBUTANE/HELIUM | 30%CH(CH3)3/He | 0836 |
| 30%CARBON DIOXIDE/AIR | 30%CO2/Air | 0508 |
| 30%GERMANE/ARGON | 30%GeH4/Ar | 0837 |
| 30%HELIUM/OXYGEN | 30%He/O2 | 0603 |
| 30%NITROGEN TRIFLUORIDE/NITROGEN | 30%NF3/N2 | 0661 |
| 30%OXYGEN/HELIUM | 30%O2/He | 0604 |
| 30%OXYGEN/HYDROGEN | 30%O2/H2 | 0637 |
| 30%PHOSPHINE/SILANE | 30%PH3/SiH4 | 0896 |
| 30%PROPANE/BUTANE | 30%C3H8/C4H10 | 0885 |
| 30%SILANE/ARGON | 30%SiH4/Ar | 0838 |
| 30%SILANE/NITROGEN | 30%SiH4/N2 | 0839 |
| 30%TRICHLOROSILANE/HYDROGEN | 30%SiHCl3/H2 | 0877 |
| 30%TRIMETHYLSILANE/HYDROGEN | 30%(CH3)3SiH/H2 | 0874 |
| 32%SILICON TETRACHLORIDE/HYDROGEN | 32%SiCl4/O2 | 0892 |
| 33.3%HYDROGEN/CARBON MONOXIDE | 33.3%H2/CO | 0840 |
| 35%PHOSPHINE/SILANE | 35%PH3/SiH4 | 0841 |
| 4%DIBORANE/NITROGEN | 4%B2H6/N2 | 0605 |
| 4%HELIUM/NITROGEN | 4%He/N2 | 0738 |

| *MIXED GAS NAME* | *SYMBOL* | *CODE* |
|---|---|---|
| 4%HYDROGEN/ARGON | 4%H2/Ar | 0700 |
| 4%HYDROGEN/HELIUM | 4%H2/He | 0606 |
| 4%HYDROGEN/NITROGEN | 4%H2/N2 | 0607 |
| 4%NITROGEN/HYDROGEN | 4%N2/H2 | 0608 |
| 4%OXYGEN/CARBON TETRAFLUORIDE(FREON-14) | 4%O2/CF4 | 0609 |
| 4%PHOSPHINE/ARGON | 4%PH3/Ar | 0691 |
| 4%PHOSPHINE/HELIUM | 4%PH3/He | 0610 |
| 4%PHOSPHINE/NITROGEN | 4%PH3/N2 | 0535 |
| 4%PHOSPHINE/SILANE | 4%PH3/SiH4 | 0611 |
| 4%SILANE/NITROGEN | 4%SiH4/N2 | 0842 |
| 4%TETRAFLUOROETHANE (FREON-134A)/44%PENTAFLUOROETHANE (FREON-125)/ ETHANE,1,1,1-TRIFLUORO-(HFC-143a) | 4%C2H2F4/44%C2HF5/C2H3F3 | 0884 |
| 4.5%PHOSPHINE/NITROGEN | 4.5%PH3/N2 | 0528 |
| 4.6%SULFUR DIOXIDE/NITROGEN | 4.6%SO2/N2 | 0906 |
| 40%ARGON/TUNGSTEN HEXAFLUORIDE | 40%Ar/WF6 | 0503 |
| 40%GERMANE/ARGON | 40%GeH4/Ar | 0751 |
| 40%GERMANE/NITROGEN | 40%GeH4/N2 | 0895 |
| 40%HELIUM/SILANE | 40%He/SiH4 | 0612 |
| 40%HYDROGEN/HELIUM | 40%H2/He | 0725 |
| 40%OXYGEN/HEXAFLUOROETHANE(FREON-116) | 40%O2/C2F6 | 0505 |
| 40%OXYGEN/SULFUR HEXAFLUORIDE | 40%O2/SF6 | 0642 |
| 40%SILANE/HELIUM | 40%SiH4/He | 0702 |
| 5%ACETONE/NITROGEN | 5%C3H6O-m)/N2 | 0711 |
| 5%AMMONIA/NITROGEN | 5%NH3/N2 | 0843 |
| 5%ARSINE/HYDROGEN | 5%AsH3/H2 | 0614 |
| 5%BENZENE/NITROGEN | 5%C6H6/N2 | 0712 |
| 5%BORON TRICHLORIDE/HYDROGEN | 5%BCI3/H2 | 0616 |
| 5%BORON TRIFLUORIDE/HELIUM | 5%BF3/He | 0776 |
| 5%CARBON DIOXIDE/10%OXYGEN/NITROGEN | 5%CO2/10%O2/N2 | 0867 |
| 5%CARBON DIOXIDE/15%OXYGEN/ NITROGEN | 5%CO2/15%O2/N2 | 0734 |
| 5%CARBON DIOXIDE/5%OXYGEN/NI TROGEN | 5%CO2/5%O2/N2 | 0865 |
| 5%CARBON DIOXIDE/NITROGEN | 5%CO2/N2 | 0618 |
| 5%CARBON MONOXIDE/ARGON | 5%CO/Ar | 0844 |
| 5%CARBON MONOXIDE/NITROGEN | 5%CO/N2 | 0862 |
| 5%CHLORINE/HELIUM | 5%CI2/He | 0719 |
| 5%DIBORANE/5%SILANE/NITROGEN | 5%B2H6/5%SiH4/N2 | 0876 |
| 5%DIBORANE/ARGON | 5%B2H6/Ar | 0615 |
| 5%DIBORANE/HELIUM | 5%B2H6/He | 0766 |
| 5%DIBORANE/HYDROGEN | 5%B2H6/H2 | 0722 |
| 5%DIBORANE/NITROGEN | 5%B2H6/N2 | 0654 |
| 5%DIBORANE/SILANE | 5%B2H6/SiH4 | 0683 |
| 5%DICHLOROSILANE/ARGON | 5%SiH2CI2/Ar | 0628 |
| 5%ETHENE/NITROGEN | 5%C2H4/N2 | 0845 |
| 5%FLUORINE/ARGON | 5%F2/Ar | 0761 |
| 5%FLUORINE/HELIUM | 5%F2/He | 0720 |

| *MIXED GAS NAME* | *SYMBOL* | *CODE* |
|---|---|---|
| 5%FLUORINE/NITROGEN | 5%F2/N2 | 0732 |
| 5%FLUORINE/NITROGEN TRIFLUORIDE | 5%F2/NF3 | 0669 |
| 5%GERMANE/HELIUM | 5%GeH4/He | 0765 |
| 5%HELIUM/ARGON | 5%He/Ar | 0846 |
| 5%HELIUM/NITROGEN | 5%He/N2 | 0752 |
| 5%HEXAFLUOROETHANE/OXYGEN | 5%C2F6/O2 | 0785 |
| 5%HYDROGEN CHLORIDE/NITROGEN | 5%HCI/N2 | 0726 |
| 5%HYDROGEN SELENIDE/HYDROGEN | 5%H2Se/H2 | 0510 |
| 5%HYDROGEN/ARGON | 5%H2/Ar | 0619 |
| 5%HYDROGEN/HELIUM | 5%H2/He | 0762 |
| 5%HYDROGEN/NITROGEN | 5%H2/N2 | 0542 |
| 5%METHANE/HELIUM | 5%CH4/He | 0699 |
| 5%NITROGEN/HYDROGEN | 5%N2/H2 | 0621 |
| 5%NITROGEN/PHOSPHINE | 5%N2/PH3 | 0622 |
| 5%OXYGEN/ARGON | 5%O2/Ar | 0623 |
| 5%OXYGEN/CARBON TETRAFLUORIDE | 5%O2/CF4 | 0753 |
| 5%OXYGEN/HELIUM | 5%O2/He | 0779 |
| 5%OZONE/OXYGEN | 5%O3/O2 | 0624 |
| 5%PHOSPHINE/5%SILANE/NITROGEN | 5%PH3/5%SiH4/N2 | 0625 |
| 5%PHOSPHINE/ARGON | 5%PH3/Ar | 0626 |
| 5%PHOSPHINE/HELIUM | 5%PH3/He | 0693 |
| 5%PHOSPHINE/HYDROGEN | 5%PH3/H2 | 0709 |
| 5%PHOSPHINE/NITROGEN | 5%PH3/N2 | 0501 |
| 5%PHOSPHINE/SILANE | 5%PH3/SiH4 | 0627 |
| 5%PHOSPHORUS PENTAFLUORIDE/HELIUM | 5%PF5/He | 0777 |
| 5%PROPANE/HYDROGEN | 5%C3H8/H2 | 0617 |
| 5%SILANE/ARGON | 5%SiH4/Ar | 0629 |
| 5%SILANE/HELIUM | 5%SiH4/He | 0780 |
| 5%SILANE/HYDROGEN | 5%SiH4/H2 | 0847 |
| 5%SILANE/NITROGEN | 5%SiH4/N2 | 0773 |
| 5%SULFUR DIOXIDE/HELIUM | 5%SO2/He | 0763 |
| 5%TETRAETHYLORTHOSILICATE(TEOS)/NITROGEN | 5%Si(C2H5O)4/N2 | 0523 |
| 5%TRICHLOROSILANE/HYDROGEN | 5%SiHCI3/H2 | 0679 |
| 5%TRIETHYLANTIMONY(TESb)/HYDROGEN | 5%(C2H5)3Sb/H2 | 0524 |
| 5%WATER VAPOR/AIR | 5%H2O/Air | 0567 |
| 5.5%ARSENIC TRICHLORIDE/HYDROGEN | 5.5%AsCl3/H2 | 0890 |
| 50%CARBON DIOXIDE/NITROGEN | 50%CO2/N2 | 0848 |
| 50%FLUORINE/ARGON | 50%F2/Ar | 0756 |
| 50%FLUORINE/HELIUM | 50%F2/He | 0757 |
| 50%FLUORINE/NITROGEN | 50%F2/N2 | 0760 |
| 50%FLUOROFORM/ARGON | 50%CHF3/Ar | 0686 |
| 50%GERMANE/ARGON | 50%GeH4/Ar | 0747 |
| 50%HELIUM/ARGON | 50%He/Ar | 0849 |
| 50%HELIUM/OXYGEN | 50%He/O2 | 0630 |
| 50%HEXAFLUOROETHANE/OXYGEN | 50%C2F6/O2 | 0769 |

| *MIXED GAS NAME* | *SYMBOL* | *CODE* |
|---|---|---|
| 50%HYDROGEN BROMIDE/HYDROGEN CHLORIDE | 50%HBr/HCI | 0650 |
| 50%HYDROGEN/NITROGEN | 50%H2/N2 | 0850 |
| 50%NITROGEN DIOXIDE/AMMONIA | 50%NO2/NH3 | 0851 |
| 50%NITROGEN/HELIUM | 50%N2/He | 0852 |
| 50%NITROGEN/OXYGEN | 50%N2/O2 | 0631 |
| 50%PHOSPHINE/NITROGEN | 50%PH3/N2 | 0518 |
| 50%PHOSPHINE/SILANE | 50%PH3/SiH4 | 0632 |
| 50%SILANE/HELIUM | 50%SiH4/He | 0521 |
| 50%SILANE/HYDROGEN | 50%SiH4/H2 | 0633 |
| 50%SULFUR DIOXIDE/NITRIC OXIDE | 50%SO2/NO | 0853 |
| 6%CARBON DIOXIDE/NITROGEN | 6%CO2/N2 | 0854 |
| 6%HYDROGEN CHLORIDE/OXYGEN | 6%HCl/O2 | 0855 |
| 6%HYDROGEN/NITROGEN | 6%H2/N2 | 0856 |
| 6%OZONE/OXYGEN | 6%O3/O2 | 0857 |
| 6.5%DIBORANE/15%SILANE/NITROGEN | 6.5%B2H6/15%SiH4/N2 | 0634 |
| 6.5%DIBORANE/HYDROGEN | 6.5%B2H6/H2 | 0635 |
| 6.5%DIBORANE/NITROGEN | 6.5%B2H6/N2 | 0858 |
| 7%CARBON DIOXIDE/10%HYDROGEN/20%CARBON MONOXIDE/NITROGEN | 7%CO2/10%H2/20%CO/N2 | 0748 |
| 7%HYDROGEN/ARGON | 7%H2/Ar | 0859 |
| 7%HYDROGEN/HELIUM | 7%H2/He | 0883 |
| 7%METHYLENE CHLORIDE/3%OZONE/AIR | 7%CH2CI2/3%O3/Air | 0685 |
| 7%OZONE/OXYGEN | 7%O3/O2 | 0901 |
| 7.5%PHOSPHINE/SILANE | 7.5%PH3/SiH4 | 0676 |
| 8%CARBON TETRAFLUORIDE(FREON-14)/OXYGEN | 8%CF4/O2 | 0574 |
| 8%DIBORANE/ARGON | 8%B2H6/Ar | 0860 |
| 8%DIBORANE/NITROGEN | 8%B2H6/N2 | 0861 |
| 8%GERMANE/HYDROGEN | 8%GeH4/H2 | 0664 |
| 8%HYDROGEN/ARGON | 8%H2/Ar | 0692 |
| 8%HYDROGEN/NITROGEN | 8%H2/N2 | 0727 |
| 8%OXYGEN/CARBON TETRAFLUORIDE(FREON-14) | 8%O2/CF4 | 0613 |
| 8%OZONE/OXYGEN | 8%O3/O2 | 0639 |
| 8%PHOSPHINE/HELIUM | 8%PH3/He | 0667 |
| 8%PHOSPHINE/NITROGEN | 8%PH3/N2 | 0620 |
| 8%PHOSPHINE/SILANE | 8%PH3/SiH4 | 0636 |
| 8%PROPANE/10%AMMONIA/AIR | 8%C3H8/10%NH3/Air | 0714 |
| 8.2%PROPANE/9.8%AMMONIA/AIR | 8.2%C3H8/9.8%NH3/Air | 0715 |
| 8.6%ARGON/NITROGEN TRIFLUORIDE | 8.6%Ar/NF3 | 0706 |
| 9.4%ARGON/NITROGEN TRIFLUORIDE | 9.4%Ar/NF3 | 0705 |

## 11 Related Document

11.1 *Data Sheet*

Schumacher Material Safety Data Sheet, No. 48.1 JN, Revision Date 8/94[14]

14 Schumacher, 1969 Palomar Oaks Way, Carlsbad, CA 92009-1307, 619.931.9555

# SEMI E56-1104
# TEST METHOD FOR DETERMINING ACCURACY, LINEARITY, REPEATABILITY, SHORT-TERM REPRODUCIBILITY, HYSTERESIS, AND DEADBAND OF THERMAL MASS FLOW CONTROLLERS

This test method was technically approved by the Global Gases Committee and is the direct responsibility of the North American Gases Committee. Current edition approved by the North American Regional Standards Committee on July 11, 2004. Initially available at www.semi.org September 2004; to be published November 2004. Originally published December 1996.

## 1 Purpose

1.1 The purpose of this document is to provide a standardized method to quantify the accuracy, linearity, repeatability, short-term reproducibility, hysteresis, and deadband of a thermal mass flow controller.

1.2 The intent of this document is not to suggest any specific testing program but to specify the test method to be used when testing for parameters that are covered by this method. The user might use this document to check significant performance characteristics such as accuracy, precison, bias, repeatability, linearity, short-term reproducibility, and deadband under a set of closely controlled test conditions.

1.3 The significance of the accuracy calculations in this method is to allow an MFC user to transfer a process from one manufacturing tool to another and to exchange MFCs within a single manufacturing tool while maintaining process control.

## 2 Scope

2.1 This document describes the conditions and procedures for testing the accuracy, linearity, repeatability, hysteresis, and deadband of thermal mass flow controllers (MFCs). Because of the generic nature of this document, not all test procedures apply to all types of MFCs.

2.2 This document provided a common basis for communication between manufacturers and users.

**NOTICE:** This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory or other limitations prior to use.

## 3 Limitations

3.1 It is not practical to evaluate performance under all possible combinations of operating conditions. This test procedure should be applied under laboratory conditions; its intent is to collect sufficient data to form a judgement of the field performance of the MFC being tested.

## 4 Referenced Standards

4.1 *SEMI Standard*

SEMI E17 — Guideline for Mass Flow Controller Transient Characteristics Tests

4.2 *ASME Standard*[1]

ASME MFC-10M — Method for Establishing Installation Effects on Flowmeters

4.3 *ISA Standard*[2]

ISA S51.1 — Process Instrumentation Terminology

**NOTICE:** Unless otherwise indicated, all documents cited shall be the latest published versions.

## 5 Terminology

5.1 *Abbreviations & Acronyms*

5.1.1 *A* — Measured Value

5.1.2 $A_a$ — average measured value

5.1.3 $A_a$ — average measured value at 100% setpoint

5.1.4 *AD* — accuracy of the DUT

5.1.5 $AD_f$ — accuracy of the flow standard

5.1.6 *AS* — accuracy of setpoint

5.1.7 $A_l$ — measured value, down cycle

5.1.8 $A_u$ — measured value, up cycle

5.1.9 *B* — bias

5.1.10 *D* — deadband value

5.1.11 *DBD* — deadband of device

1 American Society of Mechanical Engineers, Three Park Avenue, New York, NY 10016-5990, USA. Telephone: 800.843.2763 (U.S./Canada), 95.800.843.2763 (Mexico), 973.882.1167 (outside North America), Website: www.asme.org

2 Instrument Society of America, 67 Alexander Drive, Research Triangle Park, NC 27709, USA Telephone: 919.549.8411 Website: www.isa.org

5.1.12 *DBS* — deadband of setpoint

5.1.13 $D_l$ — lower deadband value

5.1.14 $D_u$ — upper deadband value

5.1.15 *DUT* — device under test

5.1.16 *FS* — full scale flow rate

5.1.17 *HD* — hysteresis of device

5.1.18 *HDBS* — hysteresis plus deadband at a setpoint

5.1.19 *HS* — hysteresis at a setpoint

5.1.20 *i* — reading number in a cycle for a given setpoint

5.1.21 *I* — intermediate value

5.1.22 *j* — cycle for a given setpoint

5.1.23 *k* — up cycle number for a given setpoint

5.1.24 *kPa* — kilopascal

5.1.25 *LD* — linearity of DUT

5.1.26 *LS* — linearity of setpoint

5.1.27 *m* — slope

5.1.28 *m* — down cycle number for a setpoint

5.1.29 *n* — number of up scale readings

5.1.30 *NC* — normally closed

5.1.31 $n_j$ — number of readings at a setpoint at a given cycle

5.1.32 *NO* — normally open

5.1.33 *P* — precision

5.1.34 *psia* — pounds per square inch absolute

5.1.35 *RPD* — repeatability of the DUT

5.1.36 *RPS* — repeatability at a setpoint

5.1.37 *S* — setpoint

5.1.38 $S_a$ — average of setpoint

5.1.39 *sccm* — standard cubic centimeters per minute

5.1.40 $S_l$ — setpoint, down cycle

5.1.41 $S_u$ — setpoint, up cycle

5.1.42 *slm* — standard liters per minute

5.1.43 *SRD* — short-term reproducibility of the device

5.1.44 *SRS* — short-term reproducibility at a setpoint

5.1.45 $v_i$ — the ith measured value at a setpoint for a given cycle

5.1.46 *Y* — ideal linearity value

5.1.47 *Z* — zero offset of DUT

5.1.48 $Z_a$ — indicated flow at zero actual flow

5.2 *Definitions*

5.2.1 *accuracy* — the closeness of agreement between an observed value and the true value; the total uncertainty of an observed value, including both precision and bias.

5.2.2 *accuracy curve* — the curve fitted through the average measured values over the specified range of the device under test.

5.2.3 *accuracy device* — the total uncertainty over a specified range of the device. Device accuracy over a range is stated as the worst case accuracy taken over all tested setpoints in this range.

5.2.4 *actual flow* — the gas flow as measured by an external standard, not the electrical output of a mass flow meter.

5.2.5 *bias* — the difference, at a setpoint, between the measured value and the sum of the setpoint value and the zero offset. The measured values of a flow standard include its total uncertainty.

5.2.6 *cardinal setpoint* — a specific setpoint to assess the accuracy of the device under test (DUT). For this test method, the cardinal setpoints are 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90%, and 100% of full scale.

5.2.7 *deadband* — the range through which a setpoint may be varied, upon reversal of direction, without initiating an observable change in output signal.

5.2.8 *device under test* — mass flow device is being tested by this method.

5.2.9 *downscale reading* — a reading approached from a setpoint greater than the current setpoint and beyond the deadband.

5.2.10 *downscale value, average* — the sum of all downscale readings, in one cycle, at a single setpoint, divided by the number of these values.

5.2.11 *drift* — the change in output over a specified time period for a constant input under specified reference operating conditions.

5.2.12 *drift, long-term* — the drift between a series of tests over a specified time interval. This specified time interval is generally much greater than the time necessary to run an individual test.

5.2.13 *drift, short-term* — the drift between sets of measurements over the duration of the test.

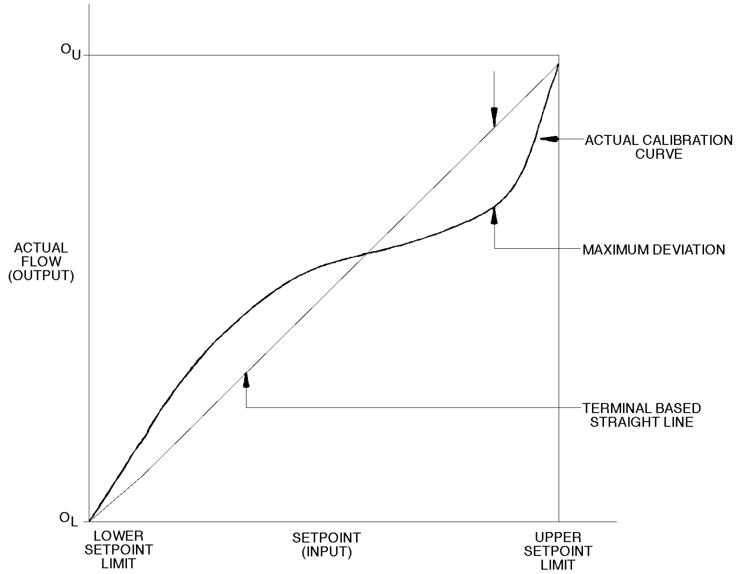


**Figure 1**
**Terminal-Based Linearity for Mass Flow Controller**

5.2.14 *hysteresis* — that property of an element evidenced by the dependence of the value of the output, for a given excursion of the input, upon the history of the prior excursions and the direction of the current traverse.

5.2.15 *indicated flow* — flow indicated by MFC under test. Electrical output of the DUT.

5.2.16 *linearity* — the closeness to which a curve approximates a straight line.

5.2.17 *linearity, terminal-based* — the maximum absolute value of the deviation of the accuracy curve (average of upscale and downscale values) from a straight line through the upper and lower setpoint limits of the accuracy curve (see Figure 1).

5.2.18 *measured value* — the actual flow through a device under test, expressed in sccm or slm, as measured by a standard, preferably primary.

5.2.19 *measured value, average* — the sum of all readings (both upscale and downscale) for all cycles, at a single setpoint, divided by the number of these readings.

5.2.20 *operating conditions, normal* — the range of operating conditions within which a device is designed to operate and for which operating influences are stated [ISA S51.1].

5.2.21 *operating conditions, reference* — the range of operating conditions of a device within which operating influences are negligible [ISA S51.1].

5.2.22 *operating influence* — the change in a performance characteristic caused by a change in a specified operating condition from reference operating conditions, all other conditions being held within the limits of reference operating conditions [ISA S51.1].

5.2.23 *pneumatic noise* — localized, random variations in pressure and flow.

5.2.24 *precision* — the closeness of agreement among the measured values at a setpoint. It is often expressed as a standard deviation.

5.2.25 *repeatability* — the closeness of agreement among a number of measured values at a setpoint, under the same operating conditions, operator, apparatus, laboratory, and short intervals of time. It is usually measured as a nonrepeatability and expressed as a repeatability in percent of reading.

5.2.26 *reproducibility* — the closeness of agreement among repeated measured values at a setpoint, within the specified reference operating conditions, made over a specified period of time, approached from both directions. Reproducibility includes hysteresis, deadband, long-term drift, and short-term reproducibility.

NOTE 1: Between repeated measurements, the input may vary over the range, and operating conditions may vary within normal operating conditions.

5.2.27 *reproducibility, short-term* — the closeness of agreement among a number of measured values at a setpoint, under the same operating conditions, operator, apparatus, laboratory and short intervals of time, approached from both directions. The approach must be from beyond the deadband. Short-term reproducibility includes repeatability, hysteresis, deadband, and short-term drift.

5.2.28 *setpoint* — the input signal provided to achieve a desired flow, reported as sccm, slm, or percent-full scale.

5.2.29 *setpoint limit, lower* — the lowest setpoint at which the instrument is specified to operate.

5.2.30 *setpoint limit, upper* — the highest setpoint at which the instrument is specified to operate, usually full scale.

5.2.31 *settling time* — the time between the set point step change and when the actual flow remains within the specified band (see SEMI E17).

5.2.32 *span* — the full-scale range of the DUT.

5.2.33 *stability* — the ability of a condition to exhibit only natural, random variation in the absence of unnatural, assignable-cause variation.

5.2.34 *standard conditions* — 101.32 kPa, 0.0°C (14.7 psia, 32°F)

5.2.35 *uncertainty, total* — the range within which the true value of the measured quantity can be expected to fit; an indication of the variability associated with a measured value that takes into account the two major components of error, bias and the random error attributed to the imprecision of the measurement process.

5.2.36 *upscale reading* — a reading approached from a setpoint less than the current setpoint and beyond the deadband.

5.2.37 *upscale value, average* — the sum of all upscale readings, in one cycle, at a single setpoint, divided by the number of these values.

5.2.38 *zero drift* — the undesired change in electrical output, at a no-flow condition, over a specified time period, reported in sccm or slm.

5.2.39 *zero offset* — the deviation from zero, at a no-flow condition, reported in sccm or slm.

## 6 Summary of Test Method

6.1 Specific procedures are given for characterizing MFCs discharging to atmospheric pressure or into a vacuum using accepted reference standards to determine accuracy, linearity, repeatability, short-term reproducibility, hysteresis, and deadband (see Figure 2).

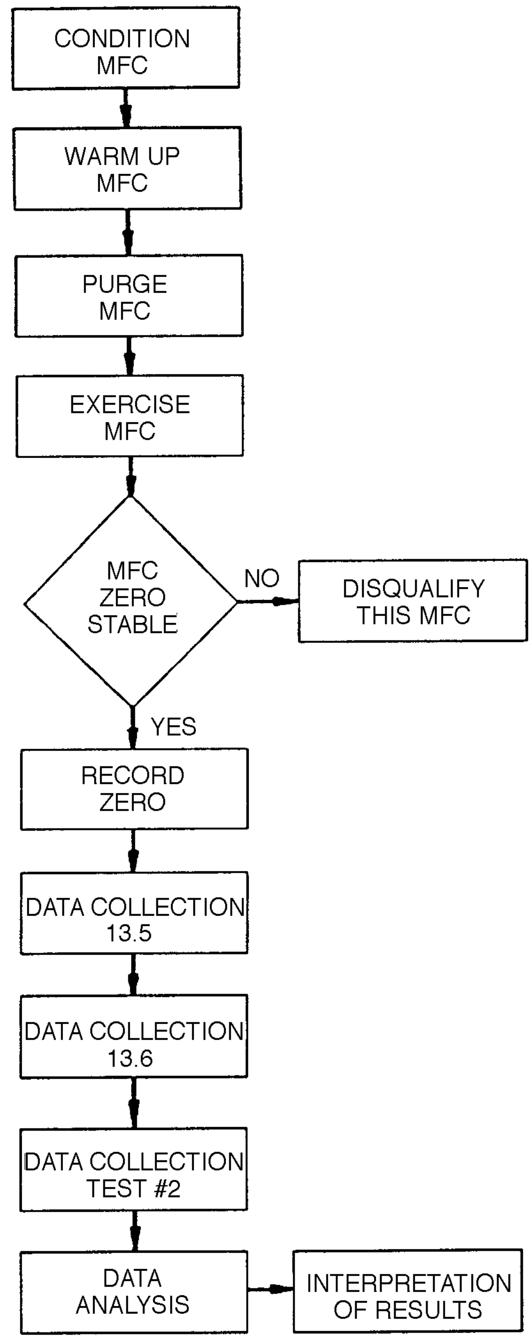


**Figure 2**
**Test Flowchart**

## 7 Interferences

7.1 The accuracy rating of the measuring equipment must include superior measurement capability compared with that of the DUT. In no instance should the accuracy rating of the measuring equipment be less than twice that of the DUT (e.g., if the accuracy of the DUT is ± 1 sccm, then the accuracy of the measuring device must be better than or equal to ± 1/2 sccm). The traceability of all the pertinent measuring instruments and devices should be realistically established and quantified.

7.1.1 In addition, take care when using test instruments with a specified accuracy expressed in percent of full scale. For example, if an instrument with a specified accuracy of ± 0.1% of full scale is used to measure the output of the DUT, but this output signal falls only within the lower third of the scale of the instrument, the effective accuracy over the range of the instrument being used may be ± 0.3%, which is unsuitable for many applications.

7.2 Use special precautions to ensure that minimum effects result from pneumatic noise in flow lines. Monitor pressure both upstream and downstream of the MFC to ensure that pneumatic noise is minimized.

7.3 The DUT should be installed so that the inlet flow can be fully developed, pulsation-free, for the specific conditions. This can be achieved by plumbing a straight length of tubing 40–50 diameters long upstream and another straight length 5 diameters long downstream of the DUT. (For additional information about inlet effects, refer to ASME MFC-10M.)

7.4 At regular calibration intervals, verify electrical signals directly at the MFC connector to ensure that there are no unacceptable line losses in the cables.

## 8 Apparatus

8.1 heat exchanger

8.2 flow standard

8.3 pressure transducer

8.4 back pressure regulator

8.5 temperature probe

8.6 digital voltmeter

8.7 setpoint generator

8.8 power supply

## 9 Technical Precautions

9.1 Many analog-to-digital converter cards do not differentiate between measurements of less than zero and zero. It may be necessary to use a digital voltmeter to record measurements below zero volts. Some MFCs do not differentiate between measurements of less than zero and zero. This may bias the results.

9.2 The manufacturer’s specifications and instructions for installation and operation must be applied during all testing.

9.3 All electrical measurements should be read on devices with at least 4.5 digits of resolution. These devices must have valid calibration certifications.

9.4 The mounting position of the device must be in accordance with the manufacturer's specifications. No external mechanical constraints beyond the manufacturer’s recommended mounting position shall be permitted.

## 10 Preparation of Apparatus

10.1 Figure 3 is a representation of a recommended generic testing apparatus. The flow standard is shown downstream of the device under test (DUT). It may be placed upstream of the DUT if the flow standard cannot be exposed to a low pressure environment. In this case, the user should be aware of possible back pressure effects on the flow standard.

10.2 The flow standard can be of any type, including laminar flow elements, volumetric standards, rate of rise, or mass flow meters.

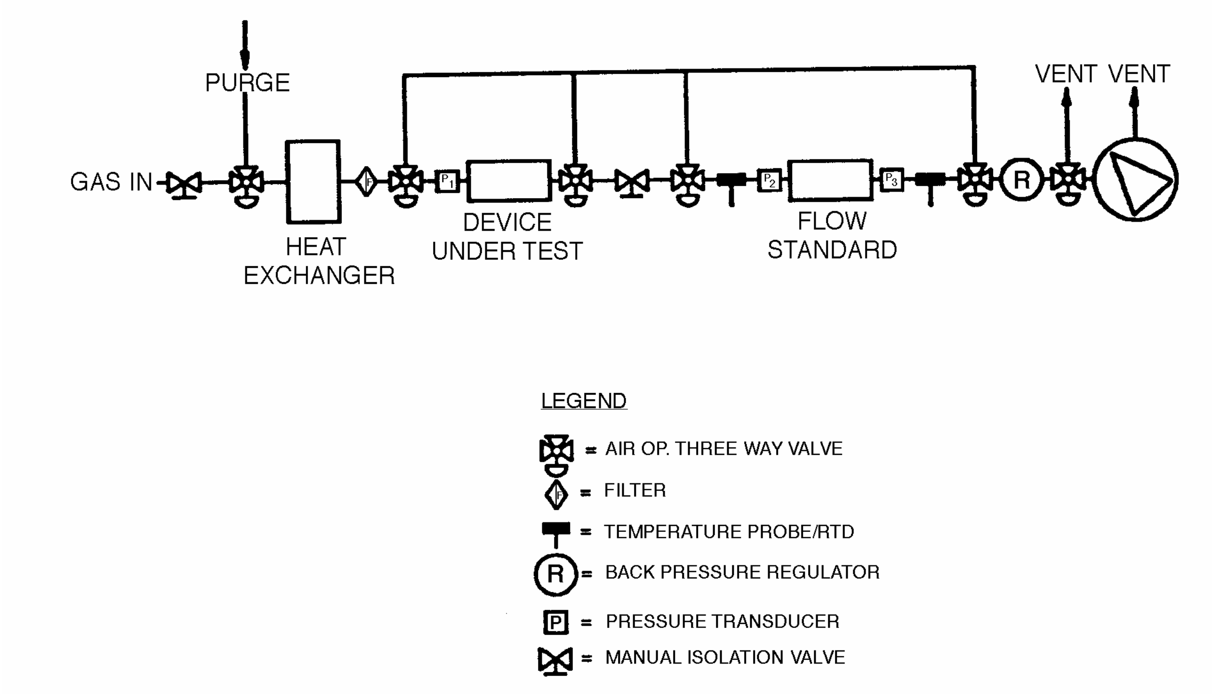


**Figure 3**
**Mass Flow Controller Test Fixture**

## 11 Calibration Standardization

11.1 All measurement devices must have valid calibration certificates.

## 12 Conditioning

12.1 Place the MFC to be tested in the testing environment. Apply power to the MFC for the 24 hours prior to initiating warm-up as defined by the manufacturer. The valve should be in its "off" position (closed for a NC valve, open for a NO valve).

12.2 Following the conditioning period, install and warm up the device according to manufacturer's specifications.

12.3 Purge the MFC with clean, dry nitrogen or argon following the warm up period.

12.4 Allow the test gas to flow through the DUT for a minimum of 10 minutes at 100% of flow.

12.5 Apply a 100% full-scale setpoint to the DUT and wait for the flow to stabilize for 10 seconds. Apply the lower setpoint limit to the DUT and wait for the flow to stabilize for 10 seconds. Repeat this cycle two more times. This process exercises the device before initiating the test.

12.6 *Test Conditions*

12.6.1 The reference operating conditions shall be as follows if the downstream pressure is atmospheric pressure:

| | |
|---|---|
| Ambient temperature | 23 ± 2°C |
| Gas temperature | Same as actual ambient |
| Ambient pressure | 101.32 kPa. (+ 4.7 or – 15.3 kPa) |
| Gas pressure $P_1$, Inlet | 274 ± 34 kPa |
| Gas pressure $P_3$, Outlet | 101.32 kPa. (+ 4.7 kPa or – 15.3 kPa) |
| Relative humidity | 40% ± 10%, noncondensing |
| Magnetic field | ≤ 50 µT |
| Electromagnetic field | < 100 µ V/m |
| Vibration | < 0.5 m/s |
| Shock | ≤ 3 g |

12.6.2 The reference operating conditions shall be as follows if the downstream pressure is at vacuum:

| | |
|---|---|
| Ambient temperature | 23 ± 2°C |
| Gas temperature | Same as actual ambient |
| Ambient pressure | 101.32 kPa. (+ 4.7 or – 15.3 kPa) |
| Gas pressure P1, Inlet | 172 ± 34 kPa |
| Gas pressure P3, Outlet | < 0.13 kPa |
| Relative humidity | 40% ± 10%, noncondensing |
| Magnetic field | ≤ 50 µT |
| Electromagnetic field | < 100 µ V/m |
| Vibration | < 0.5 m/s |
| Shock | ≤ 3 g |

12.7 *Power Supply Conditions*

12.7.1 The reference power supply conditions used shall be the reference values specified by the manufacturer. For those instances when a range of values is specified rather than a reference value, the midpoint of the range shall be taken to be the reference value.

12.7.2 The reference power supply must be sufficiently rated for the DUT. In addition, the following supply conditions and tolerances shall apply:

| | |
|---|---|
| DC supply reference voltage | ± 0.1% of operating voltage |
| Noise and ripple of DC supply | ≤ 0.1% rms |

## 13 Procedure

13.1 *Zero Offset* — Close the gas shut-off valve upstream of the DUT and apply a 100% setpoint to the DUT to equilibrate the pressure across the MFC. Wait for the flow to stabilize at a value near zero; then close the downstream shut-off valve. Deactivate the MFC's control valve (open for (NO) valves, closed for (NC) valves), and allow the MFC to auto-zero if the an auto-zero option is available. After the electrical output signal has stabilized for at least three minutes, record the MFC zero offset in Table 1. (Consult the manufacturer's specifications for the stabilization time and report this time on Table 2.)

**Table 1 Data Tabulation**

| *Input %* | *Set Point (sccm)* | *Indicated Flow (sccm)* | *Actual Flow (sccm)* |
|---|---|---|---|
| 40 | Wait 5 minutes. | Record no data. | |
| 50 | | | |
| 60 | | | |
| 70 | | | |
| 80 | | | |
| 90 | | | |
| 100 | | | |
| 90 | | | |
| 80 | | | |
| 70 | | | |
| 60 | | | |
| 50 | | | |
| 40 | | | |
| 30 | | | |
| 20 | | | |
| 10 | | | |
| 5 | | | |
| Minimum [#1] | | | |
| 5 | | | |
| 10 | | | |
| 20 | | | |
| 30 | | | |
| 40 | | | |
| 50 | | | |
| 60 | | | |

| *Input %* | *Set Point (sccm)* | *Indicated Flow (sccm)* | *Actual Flow (sccm)* |
|---|---|---|---|
| 70 | | | |
| 80 | | | |
| 90 | | | |
| 100 | | | |
| 90 | | | |
| 80 | | | |
| 70 | | | |
| 60 | | | |
| 50 | | | |
| 40 | | | |
| 30 | | | |
| 20 | | | |
| 10 | | | |
| 5 | | | |
| Minimum [#1] | | | |
| 5 | | | |
| 10 | | | |
| 20 | | | |
| 30 | | | |
| 40 | | | |
| 50 | | | |
| 60 | | | |
| 70 | | | |
| 80 | | | |
| 90 | | | |
| 100 | | | |
| 90 | | | |
| 80 | | | |
| 70 | | | |
| 60 | | | |
| 50 | | | |
| 40 | | | |
| 30 | | | |
| 20 | | | |
| 10 | | | |
| 5 | | | |
| Minimum [#1] | | | |
| 5 | | | |
| 10 | | | |
| 20 | | | |
| 30 | | | |
| 40 | | | |
| 50 | | | |

[#1] Per Section 13.5.4.1

[#2] Test for accuracy, linearity, repeatability, short-term reproducibility, and hysteresis.

Table 2 Test Data Cover Sheet

| MFC | | | |
|---|---|---|---|
| Manufacturer________ | Model________ | Serial Number_________ | Attitude________ |
| Nameplate Gas________ | Seal Material________ | Valve Seat Material________ | Full Scale Range________ |
| *Environment* | | | |
| Ambient Temp. (°C)_______ | Ambient Press. (kPa)_______ | Humidity (%)________ | |
| Test Gas________ | Inlet Gas Press. (Kpa)______ | Outlet Gas Press. (kPa)_______ | Gas Temp. (°C)_______ |
| *Test Facility* | | | |
| Name________ | City/State________ | Telephone ( )_________ | Fax ( )__________ |
| Standard Used________ | Standard Accuracy________ | Facility Bias_______ | Certification Date________ |
| Other Equipment________ | Accuracy________ | Certification Date_______ | |
| Other Equipment________ | Accuracy________ | Certification Date_______ | |
| Other Equipment________ | Accuracy________ | Certification Date_______ | |
| Other Equipment________ | Accuracy________ | Certification Date_______ | |
| Comments or Special Instructions:________ Technical:________ Date:________ | | | |

13.2 Use the cardinal setpoints and any other setpoints of specific interest. These setpoints will be used to determine the accuracy of the MFC. The setpoint increments should exceed the expected deadband of the DUT.

13.3 At each setpoint under test, maintain the input signal until the output of the DUT becomes stabilized at its apparent final value. Observe and record the output values in Table 1 for each input value.

13.4 Record five readings at each setpoint during testing. The time between readings shall be between 1 and 100 times the settling time of the DUT.

NOTE 2: If the data points show a trend in one direction, either up or down, the DUT is not stable enough for the test to proceed to the next setpoint. Record another five readings at this setpoint. If the results continue to show a trend, repeat the measurements at the previous setpoint. If the results are not satisfactory at this setpoint, stop the test for this MFC. If the results are not satisfactory, halt the test and verify the performance of the testing apparatus.

13.5 *Test for Accuracy, Linearity, Repeatability, Short-Term Reproducibilty, and Hysteresis*

NOTE 3: Record data in Table 1.

13.5.1 Provide a setpoint to the DUT of 40% and hold it there for 5 minutes. Do not collect any data at this point. Apply a 50% setpoint to the MFC and record data.

13.5.2 Begin collecting data at the midpoint of the span. Use data tabulation table in Table 1.

13.5.3 Step the MFC's setpoint to the upper setpoint limit in the increments previously chosen; record data at each setpoint.

13.5.4 After data is recorded at the upper setpoint limit, step the setpoint to the lowest setpoint chosen, again taking data at each of the intermediate setpoints.

13.5.4.1 If the lowest setpoint chosen is greater than the lower setpoint limit, apply the lower setpoint limit to the device and wait for five minutes. This allows hysteresis to be calculated at the lowest setpoint chosen.

13.5.5 Continue collecting data, increasing the setpoint until the midpoint of the span is reached again.

13.5.6 Perform the cycle described in Sections 13.5.1–13.5.4 a total of three times.

13.6 *Test for Deadband*

13.6.1 Begin collecting data at the lowest setpoint chosen. Record on Table 3.

**Table 3 Data Tabulation**

| *Setpoint* | *Lower Deadband (sccm)* | *Upper Deadband (sccm)* |
|---|---|---|
| 10% | | |
| 20% | | |
| 30% | | |
| 40% | | |
| 50% | | |
| 60% | | |
| 70% | | |
| 80% | | |
| 90% | | |
| 100% | | |

13.6.2 Step the MFC's setpoint to the highest setpoint chosen that is less than the upper setpoint limit in the increments previously chosen; record data at each setpoint.

13.6.3 At each setpoint, slowly increase the setpoint signal to the DUT until a detectable flow output change is observed in the flow standard.

13.6.4 Record the setpoint signal when the flow output changes and call this the upper deadband value.

13.6.5 Return to the setpoint selected in Section 13.6.3.

13.6.6 Slowly decrease the setpoint signal until a detectable flow output change is observed.

13.6.7 Record the setpoint signal and call it the lower deadband value. Use Table 3.

## 14 Data Analysis

14.1 *Calculations*

NOTE 4: NOTE: Record calculations on Table 4.

**Table 4 Worksheet for Table 1**

| *Setpoint* | *Up Ave. Flow (sccm)* | *Down Ave. Flow (sccm)* | *Up/Down Ave. Flow (sccm)* | *Precision (sccm)* | *Bias (sccm)* | *Accuracy (%)* | *Linearity (%)* | *Repeatability* | *Reproducibility* |
|---|---|---|---|---|---|---|---|---|---|
| 0 | | | | | | | | | |
| 10 | | | | | | | | | |
| 20 | | | | | | | | | |
| 30 | | | | | | | | | |
| 40 | | | | | | | | | |
| 50 | | | | | | | | | |
| 60 | | | | | | | | | |
| 70 | | | | | | | | | |
| 80 | | | | | | | | | |
| 90 | | | | | | | | | |
| 100 | | | | | | | | | |
| Over-all | | | | | | | | | |

14.1.1 *Accuracy*

14.1.1.1 Determine the precision at a setpoint by calculating the standard deviation of all the measured values (both upscale and downscale) for that setpoint. Perform this calculation at each setpoint.

$$P = \frac{\sqrt{\Sigma(\Sigma(v_i - A_a)^2)_j}}{\Sigma n_j}$$

$P$ = Precision
$v_i$ = The ith measured value at a setpoint for a given cycle
$A_a$ = Average measured value
$n_j$ = Number of readings at a setpoint at a given cycle
$i$ = Reading number in a cycle for a given setpoint
$j$ = Cycle for a given setpoint

14.1.1.2 Determine the bias at a setpoint by averaging the difference between the measured value and the sum of the setpoint and zero offset. Perform this calculation at each setpoint.

$$B = \frac{\Sigma[\Sigma(A - S - Z)_i]_j}{\Sigma n_j}$$

$B$ = Bias
$A$ = Measured Value
$S$ = Setpoint
$Z$ = Zero offset of DUT

14.1.1.3 Determine the accuracy at each setpoint by summing the absolute values of the precision and bias. Divide the sum by the average of the setpoint and multiply by 100%. The sign of the accuracy is the same as the sign of the bias. Perform this calculation at each setpoint.

$$AS\% = \frac{|P| + |B|}{S_a} \times 100 \times \left(\frac{B}{|B|}\right)$$

$AS$ = Accuracy of setpoint
$S_a$ = Average of setpoint

14.1.1.4 Determine the overall accuracy of the DUT by adding the absolute value of the flow standard accuracy to the maximum absolute accuracy value from Section 14.1.1.3. This value is expressed as ± percentage of reading.

NOTE 5: This assumes that the flow standard accuracy is expressed as a percentage of reading.

$$\pm AD\% = |AS|_{MAX} + |AD_f|$$

$AD$ = Accuracy of the DUT
$AD_f$ = Accuracy of the flow standard

14.1.2 *Linearity*

14.1.2.1 Determine an equation for the straight line passing through the indicated flow at zero actual flow and the average measured value at a 100% setpoint.

$$m = \frac{A_a - Z_a}{100}$$

$$Y = mS + b$$

$Z_a$ = Indicated flow at zero actual flow
$A_a$ = Average measured value at 100% setpoint
$m$ = Slope
$Y$ = Ideal linearity value

14.1.2.2 Determine the linearity at a setpoint by averaging the difference between the measured value and the value of y at a given setpoint. Divide this number by the full scale range of the DUT and multiply by 100. Perform this calculation at each setpoint. Record this value in Figure 7.

$$LS\% = \frac{\Sigma[\Sigma(A - Y)_i]_j}{FS\,\Sigma n_j} \times 100$$

$LS$ = Linearity of setpoint
$FS$ = Full scale flow rate

14.1.2.3 The overall linearity of the DUT is the maximum absolute value calculated in Section 14.1.2.2. This value is expressed as a ± percentage of full scale.

$$\pm LD\% = |LS|_{\max}$$

$LD$ = Linearity of DUT

14.1.3 *Repeatability*

14.1.3.1 Determine the intermediate value by calculating the standard deviation of the measured values for all cycles approaching from a given direction. Divide this by the average setpoint for these cycles. Perform this calculation at each setpoint for both directions. The 100% setpoint will only be approached from the upscale direction.

$$I\% = \frac{\sqrt{\frac{\Sigma(v_i - A_a)^2}{n_j}}}{S_a} \times 100$$

$I$ = Intermediate value

14.1.3.2 The repeatability at a setpoint is the maximum intermediate value at each setpoint calculated in Section 14.1.3.1. This value is expressed as a ±

percentage of reading. Perform this calculation at each setpoint.

$$\pm RPS = I_{\max}$$

$RPS$ = Repeatability at a setpoint

14.1.3.3 The overall repeatability of the DUT is the maximum value calculated in Section 14.1.3.2.

$$\pm RPD = RPS_{\max}$$

$RPD$ = Repeatability of the DUT

14.1.4 *Short-Term Reproducibility*

14.1.4.1 Determine the short-term reproducibility at a setpoint by dividing the precision of the setpoint by the average setpoint. This is expressed as a percentage of reading. Perform this calculation a each setpoint.

$$SRS = \frac{P}{S_a} \times 100$$

$SRS$ = Short - term reproducibility at a setpoint

14.1.4.2 The overall short-term reproducibility of the DUT is the maximum value calculated in Section 14.1.4.1.

$$\pm SRD = SRS_{\max}$$

$SRD$ = Short - term reproducibility of the device

14.1.5 *Deadband*

14.1.5.1 Determine the absolute deadband value by subtracting the lower deadband value from the upper value at each setpoint. Perform this calculation at each setpoint.

$$D = D_u - D_l$$

$D$ = Deadband value

$D_u$ = Upper deadband value

$D_l$ = Lower deadband value

14.1.5.2 Determine the deadband at setpoint by dividing the absolute deadband value by the initial setpoint and multiplying by 100. This is expressed as a percentage of reading. Perform this calculation at each setpoint.

$$DBS = \frac{D}{S} \times 100$$

$DBS$ = Deadband of setpoint

14.1.5.3 The overall deadband of the DUT is the maximum value calculated in Section 14.1.5.2.

$$\pm DBD = DBS_{\max}$$

$DBD$ = Deadband of device

14.1.6 *Hysteresis*

14.1.6.1 Determine the hysteresis plus deadband by subtracting the average of the difference between the downscale measured value and the downscale setpoint from the average of the difference between the upscale measured value and the upscale setpoint. Perform this calculation at each setpoint.

$$HDBS = \frac{\Sigma[\Sigma(A_u - S_u)_i]_k}{\Sigma n_k} - \frac{\Sigma[\Sigma(A_l - S_l)_i]_n}{\Sigma n_m}$$

$HDBS$ = Hysteresis plus deadband at a setpoint

$A_u$ = Measured value, up cycle

$A_l$ = Measured value, down cycle

$S_u$ = Setpoint, up cycle

$S_l$ = Setpoint, down cycle

$n$ = Number of up scale readings

$k$ = Up cycle number for a given setpoint

$m$ = Down cycle number for a setpoint

14.1.6.2 Determine the hysteresis by subtracting the deadband from hysteresis plus deadband and divide the result by the initial setpoint and multiply by 100. This is expressed as a percentage of reading. Perform this calculation at each setpoint.

$$HS = \frac{HDBS - D}{S} \times 100$$

$HS$ = Hysteresis at a setpoint

14.1.6.3 The overall hysteresis of the DUT is the maximum value calculated in Section 14.1.6.2.

$$\pm HD\% = HS_{\max}$$

$HD$ = Hysteresis of devi

## 15 Data Presentation

15.1 *Accuracy* — Plot the accuracy data at each setpoint on a graph. The x-axis is the setpoint, and the y-axis is accuracy as a percentage of the reading.

15.2 *Linearity* — Plot the linearity at each setpoint on a graph. The x-axis is the setpoint, and the y-axis is linearity as a percentage of full scale.

15.3 *Repeatability* — Report a single number, as calculated above, as a percentage of the reading.

15.4 *Hysteresis* — Report a single number, as calculated above.

15.5 *Deadband* — Report a single number, as calculated above.

## 16 Related Documents

16.1 *SEMI Standard*

SEMI E28 — Guideline for Pressure Specifications of the Mass Flow Controller

SEMI E67 — Test Method for Determining Reliability of Mass Flow Controller (refer to this standard if reliability data is needed for some of the parameters tested in this method)

16.2 *ANSI Standards*[3]

ANSI C39.5 — Safety Requirements for Electrical and Electronic Measuring and Controlling Instrumentation

ANSI C42.100 — Dictionary of Electrical and Electronics Terms

ANSI MC4.1 — Dynamic Response Testing of Process Control Instrumentation

16.3 *ASME Standard*[4]

ASME MFC-1M — Glossary of Terms Used in the Measurement of Fluid Flow in Pipes

16.4 *IEC Standards*[5]

IEC 160 — Standard Atmospheric Conditions for Test Purposes

IEC 546 — Methods of Evaluating the Performance of Controllers with Analogue [sic] Signals for Use in Industrial Process Control

16.5 *ISA Standard*[6]

ISA S7.3 — Quality Standards for Instrument Air

3 American National Standards Institute, Headquarters: 1819 L Street, NW, Washington, DC 20036, USA. Telephone: 202.293.8020; Fax: 202.293.9287, New York Office: 11 West 42nd Street, New York, NY 10036, USA. Telephone: 212.642.4900; Fax: 212.398.0023, Website: www.ansi.org

4 American Society of Mechanical Engineers, Three Park Avenue, New York, NY 10016-5990, USA. Telephone: 800.843.2763 (U.S./Canada), 95.800.843.2763 (Mexico), 973.882.1167 (outside North America), Website: www.asme.org

5 International Electrotechnical Commission, 3, rue de Varembé, Case Postale 131, CH-1211 Geneva 20, Switzerland. Telephone: 41.22.919.02.11; Fax: 41.22.919.03.00, Website: www.iec.ch

6 Instrument Society of America, 67 Alexander Drive, Research Triangle Park, NC 27709 USA Telephone: 919.549.8411 Website: www.isa.org

# SEMI E57-0600 (Reapproved 0305)
# MECHANICAL SPECIFICATION FOR KINEMATIC COUPLINGS USED TO ALIGN AND SUPPORT 300 mm WAFER CARRIERS

This specification was technically reapproved by the Global Physical Interfaces and Carriers Committee and is the direct responsibility of the North American Physical Interfaces and Carriers Committee. Current edition approved by the North American Regional Standards Committee on November 4, 2004. Initially available at www.semi.org January 2005; to be published March 2005. Originally published in 1996; previously published June 2000.

## 1 Purpose

1.1 This standard specifies the mechanical couplings used to ergonomically align and precisely support 300 mm wafer carriers (including transport cassettes, process cassettes, quartz boats, pods, lot boxes, and shipping boxes). Such a kinematic coupling can be used at several interfaces, including:

- between a box or cassette and a tool load-port or vehicle nest,
- between a transport cassette and a box, and
- between a process cassette or quartz boat and the floor of a process chamber.

## 2 Scope

2.1 This standard is intended to set an appropriate level of specification that places minimal limits on innovation while ensuring modularity and inter-changeability at all mechanical interfaces. Only the bottom half of the kinematic coupling is specified so that suppliers can be flexible in designing wafer carriers that can mate with it.

**NOTICE:** This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory or other limitations prior to use.

## 3 Referenced Standards

3.1 *SEMI Standards*

SEMI E15 — Specification for Tool Load Port

SEMI E19 — Standard Mechanical Interface (SMIF)

SEMI E19.4 — 200 mm Standard Mechanical Interface (SMIF)

3.2 *ISO Document*[1]

ISO 4287 — Geometrical Product Specifications (GPS) — Surface texture: Profile method — Terms, definitions and surface texture parameters

**NOTICE:** Unless otherwise indicated, all documents cited shall be the latest published versions.

## 4 Terminology

4.1 *Definitions*

4.1.1 *bilateral datum plane* — a vertical plane that bisects the wafers and that is perpendicular to both the horizontal and facial datum planes.

4.1.2 *box* — a protective portable container for a cassette and/or substrate(s).

4.1.3 *cassette* — a open structure that holds one or more substrates.

1 International Organization for Standardization, ISO Central Secretariat, 1, rue de Varembé, Case postale 56, CH-1211 Geneva 20, Switzerland. Telephone: 41.22.749.01.11; Fax: 41.22.733.34.30, Website: /www.iso.ch

4.1.4 *facial datum plane* — a vertical plane that bisects the wafers and that is parallel to the front side of the carrier (where wafers are removed or inserted). On tool load ports, it is also parallel to the load face plane specified in SEMI E15 on the side of the tool where the carrier is loaded and unloaded.

4.1.5 *horizontal datum plane* — a horizontal plane from which projects the kinematic-coupling pins on which the carrier sits. On tool load ports, it is at the load height specified in SEMI E15 and might not be physically realized as a surface.

4.1.6 *nominal wafer center line* — the line that is defined by the intersection of the two vertical datum planes (facial and bilateral) and that passes through the nominal centers of the seated wafers (which must be horizontal when the carrier is placed on the coupling).

4.1.7 *pod* — a box having a Standard Mechanical Interface (SMIF) per SEMI E19.

4.1.8 *wafer carrier* — any cassette, box, pod, or boat that contains wafers (as defined in SEMI E15).

## 5 Requirements

5.1 *Kinematic Coupling Pin Shapes* — The physical alignment interface on the bottom of the wafer carrier consists of features (not specified in this standard) that mate with six pins underneath. As shown in Figure 1 and defined in Table 1, each pin is radially symmetric about the vertical center axis line and can be seen as the intersection of a cylinder of diameter *d*91 and a sphere of radius *r*93 (which might contact a flat plate). An additional rounding radius *r*95 provides contact with angled mating surfaces, and blend radii *r*94 and *r*96 smooth the resulting edges. The final roughness height of the over-all surface finish must be less than or equal to *r*97. Dimensions *r*92 and *z*91 have zero tolerance because they only give a distance to another toleranced dimension. (Dimensions in parenthesis are not part of the requirements in this standard but are intended to clarify the preparation of manufacturing instructions.)

5.2 *Kinematic Coupling Pin Locations* — The pins are arranged in three sets with two pins in each set. As shown in Figure 2, the outer pin in each set is designated the primary pin for use on a tool load-port or vehicle nest or inside a box, and the inner pin in each set is designated the secondary pin for use on a robotic arm that would pick up the carrier (typically from the side opposite the load face plane). The location of each pin is determined with respect to the three orthogonal datum planes defined in §4: the horizontal datum plane, the facial datum plane, and the bilateral datum plane. Figure 3 shows the locations of the kinematic coupling pins as viewed from above, and Table 2 defines the locations (all of which are bilaterally symmetric about the bilateral datum plane). Angle θ is shown in Figure 3 for clarity and is not part of the requirements in this standard.

5.3 *Empirical Determination of Datum Plane Locations* — Given a set of three primary or secondary kinematic coupling pins, the datum planes should be determined as follows. The two pins that are closest together are the front pins which (along with a known vertical direction) define a Cartesian coordinate system. The center axis line of each pin is defined to be the vertical line whose *x* (left-right) coordinate is the average of the maximum protrusions of the pin to the left and to the right and whose *y* (front-back) coordinate is the average of the maximum protrusions of the pin to the front and to the back. The bilateral datum plane is defined to be the vertical plane that contains the center axis line of the rear pin and that is equally distant from the center axis lines of the front pins. The facial datum plane is defined to be the vertical plane that is perpendicular to the bilateral datum plane and whose distance to the center axis line of the rear pin is 1.5 times the average of the distances to the center axis lines of the front pins. The horizontal datum plane is defined to be the horizontal plane that is 13 mm (0.51 in.) below the average of the heights of the highest and lowest pin tops. Once these datum planes have been determined, the three kinematic coupling pins can be evaluated to see if they conform to ¶¶5.1 and 5.2 of this specification. If they comply, the kinematic coupling pins and datum planes can be used to evaluate the compliance of carriers to standards cited in §6.

## 6 Related Documents

6.1 *SEMI Standards*

SEMI E1.9 — Mechanical Specification for Cassettes Used to Transport and Store 300 mm Wafers

SEMI E47.1 — Provisional Mechanical Specification for Boxes and Pods Used to Transport and Store 300 mm Wafers

SEMI E62 — Provisional Specification for 300 mm Front-Opening Interface Mechanical Standard (FIMS)

SEMI E63 — Mechanical Specification for 300 mm Box Opener/Loader to Tool Standard (BOLTS-M) Interface

SEMI M31 — Provisional Mechanical Specification for Front-Opening Shipping Box Used to Transport and Ship 300 mm Wafers

6.2 *Other Documents*

Alexander H. Slocum, *Precision Machine Design*, Society of Manufacturing Engineers, Item Code 2597, 1992 (originally published by Prentice-Hall, 1992)

**Table 1 Kinematic Coupling Pin Dimensions**

| *Symbol Used* | *Value Specified* | *Dimension Description* |
|---|---|---|
| *d*91 | 12 ± 0.05 mm (0.4724 ± 0.002 in.) | Diameter of pin centered on the center axis line. |
| *r*92 | 6 mm (0.2362 in.) | Radial distance from the center axis line to the origin of the shoulder radius *r*95. |
| *r*93 | 15 ± 0.05 mm (0.5906 ± 0.002 in.) | Radial distance from the intersection of the center axis line and *z*91 to the top of the pin. |
| *r*94 | 2 ± 0.1 mm (0.0787 ± 0.004 in.) | Blend radius for the intersection of *r*93 and *r*95. |
| *r*95 | 15 ± 0.05 mm (0.5906 ± 0.002 in.) | Radial distance from the intersection of the horizontal datum plane and *r*92 to the far shoulder of the pin. |
| *r*96 | 2 ± 0.1 mm (0.0787 ± 0.004 in.) | Blend radius for the intersection of *r*95 and *d*91. |
| *r*97 | 0.30 μm (12 μin.) maximum | Roughness ($R_a$) as defined in *ISO 4287.* |
| *z*91 | 2 mm (0.08 in.) | Vertical distance from the horizontal datum plane to the origin of top radius *r*93. |

**Table 2 Distances to the Center Axis Lines of the Coupling Pins**

| *Symbol Used* | *Value Specified* | *Datum Plane Measured from* | *Pin Center Axis Line(s) Measured to* |
|---|---|---|---|
| *r*97 | 0.30 μm (12 μin.) maximum | Roughness ($R_a$) as defined in *ISO 4287* | *r*97 |
| *x*91 | 115 ± 0.05 mm (4.5276 ± 0.002 in.) | bilateral | front right and left primary |
| *x*92 | 92 ± 0.05 mm (3.6220 ± 0.002 in.) | bilateral | front right and left secondary |
| *y*91 | 80 ± 0.05 mm (3.1496 ± 0.002 in.) | facial | front right and left primary |
| *y*92 | 120 ± 0.05 mm (4.7244 ± 0.002 in.) | facial | rear primary |
| *y*93 | 64 ± 0.05 mm (2.5197 ± 0.002 in.) | facial | front right and left secondary |
| *y*94 | 96 ± 0.05 mm (3.7795 ± 0.002 in.) | facial | rear secondary |

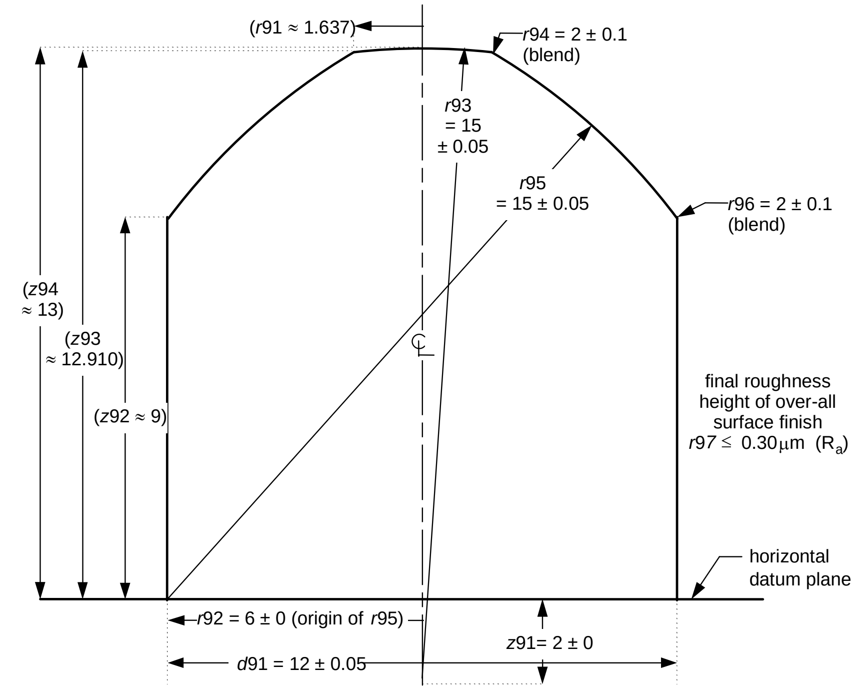


**Figure 1**
**Kinematic Coupling Pin Shape**

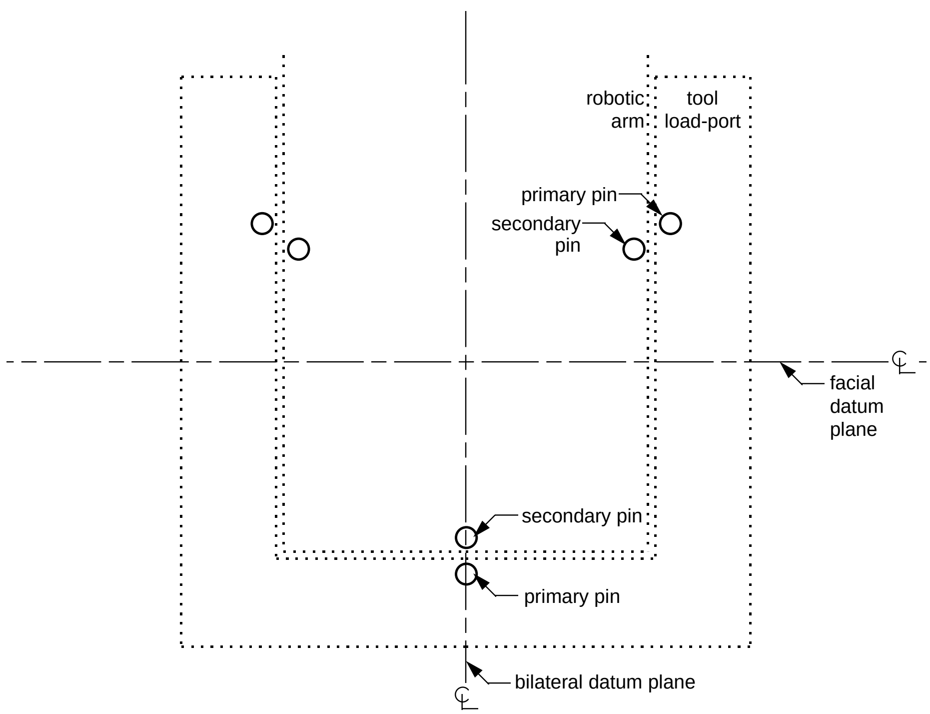


**Figure 2**
**Primary and Secondary Kinematic Coupling Pins**

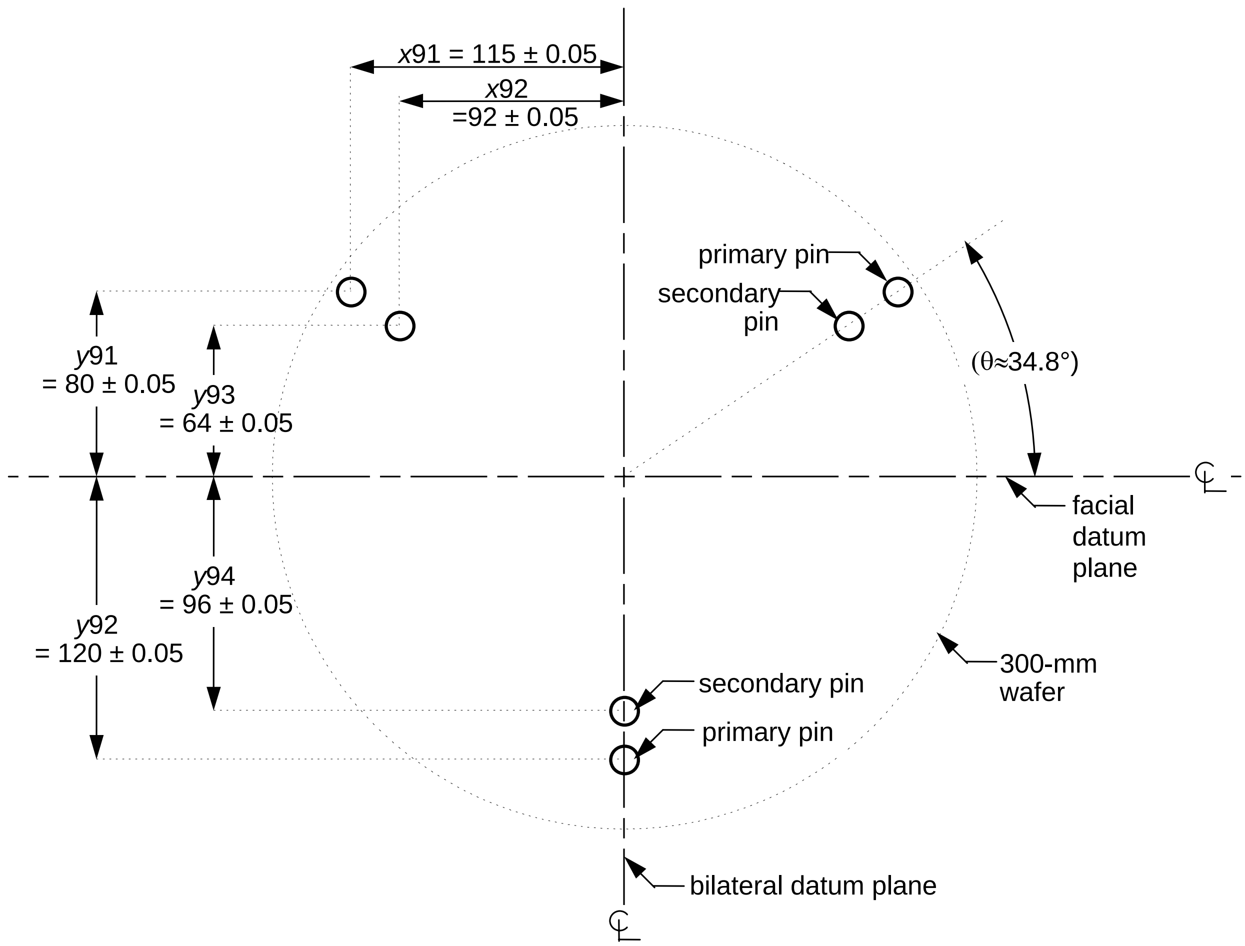


**Figure 3**
**Kinematic Coupling Pin Locations**

# RELATED INFORMATION 1
# APPLICATION NOTES

**NOTICE**: This related information is not an official part of SEMI E57. This related information was approved for publication by full letter ballot procedures.

R1-1 The three features on the bottom of the wafer carrier that mate with the six pins underneath are not specified in this standard. These three features are recommended to be inverted V-shaped grooves, each of which extends along a line that is perpendicular to, and co-planar with, the nominal wafer center line (as shown in Figure R1-1). Such grooves are likely to work well even when shrunken or slightly misaligned (such as when they do not all line up with the nominal wafer center line). Other mating features are also possible, such as those shown in Figure R1-2 where one pin is contacted on the top. Front-opening boxes may need to contact the pins on the side to provide pressure against a front mechanical interface. Such options are why the top and sides of the pins are toleranced so tightly. When designing the mating features on the bottom of the wafer carrier, it is suggested that designers follow the recommendations given in the book (listed in §6) by Dr. Alexander H. Slocum.

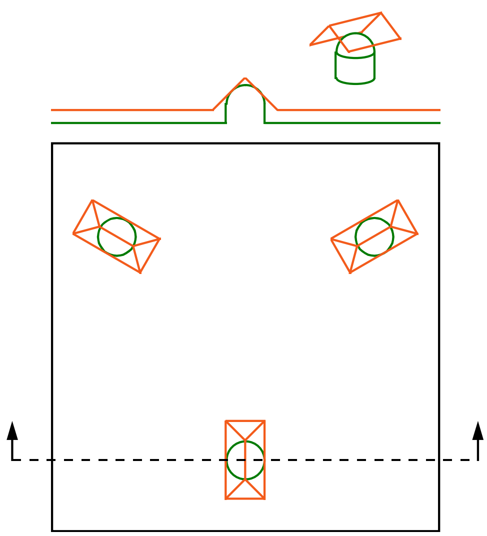

**Figure R1-1**
**Recommended Mating Features**

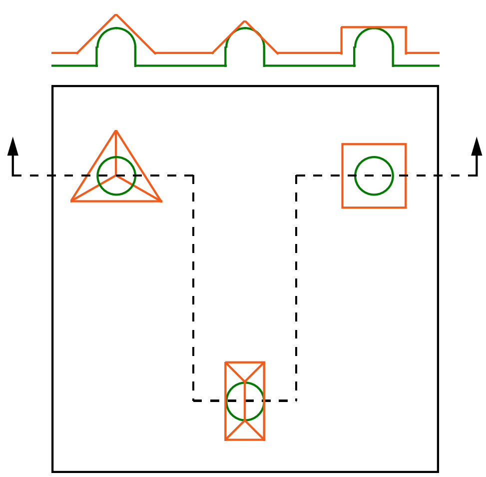

**Figure R1-2**
**Alternative Mating Features**

R1-2  All of the dimensions for the kinematic coupling pin surfaces and locations are given as ranges so that any roundness, cylindricity, perpendicularity, bending, or misalignment of the pins must be contained within the limits given.

R1-3  As shown in Figure R1-3, these couplings can also be used to support 200 mm pods as an addition to the requirements given in SEMI E19.4. However, concurrent implementations for both 200 and 300 mm wafer carriers may be covered by patent claims.

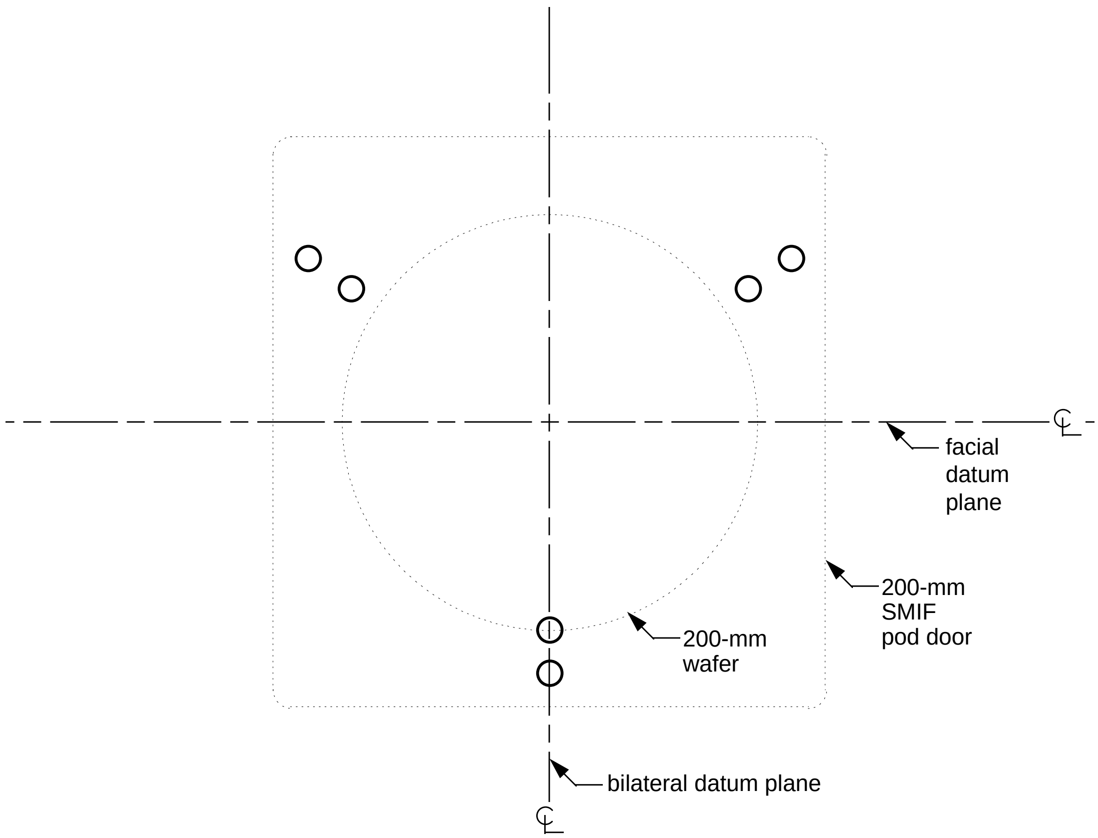


**Figure R1-3**
**Application to 200 mm Pods**

**NOTICE:** SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature, respecting any materials or equipment mentioned herein. These standards are subject to change without notice.

By publication of this standard, Semiconductor Equipment and Materials International (SEMI) takes no position respecting the validity of any patent rights or copyrights asserted in connection with any items mentioned in this standard. Users of this standard are expressly advised that determination of any such patent rights or copyrights, and the risk of infringement of such rights are entirely their own responsibility.

# SEMI E62-0705
# PROVISIONAL SPECIFICATION FOR 300 mm FRONT-OPENING INTERFACE MECHANICAL STANDARD (FIMS)

This provisional specification was technically approved by the global Physical Interfaces & Carriers Committee. This edition was approved for publication by the global Audits and Reviews Subcommittee on April 7, 2005. It was available at www.semi.org in June 2005 and on CD-ROM in July 2005. Originally published in 1997; previously published March 2003.

## 1 Purpose

1.1 This standard specifies the tool side of the interface between a process or metrology tool and a front-opening box used to transport and store 300 mm wafers (which may or may not be in removable cassettes) in an IC factory.

## 2 Scope

2.1 This standard is intended to set an appropriate level of specification that places minimal limits on innovation while ensuring modularity and interchange-ability at all mechanical interfaces. Only the physical interface is specified; no materials requirements or micro-contamination limits are given. The interface specified in this standard can be for a sealed mini-environment, but it could also just be a well-defined automation interface.

2.2 This standard is provisional because the front-opening interface is a new technology. Once interface testing is done, this standard should be modified and upgraded from provisional status.

**NOTICE:** This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory or other limitations prior to use.

## 3 Referenced Standards and Documents

3.1 *SEMI Standards*

SEMI E1.9 — Mechanical Specification for Cassettes Used to Transport and Store 300 mm Wafers

SEMI E15 — Specification for Tool Load Port

SEMI E19 — Standard Mechanical Interface (SMIF)

SEMI E47.1 — Provisional Mechanical Specification for Boxes and Pods Used to Transport and Store 300 mm Wafers

SEMI E57 — Mechanical Specification for Kinematic Couplings Used to Align and Support 300 mm Wafer Carriers

3.2 *ISO Standard*[1]

ISO 4287 — Geometrical Product Specifications (GPS) — Surface texture: Profile method — Terms, definitions and surface texture parameters

**NOTICE:** Unless otherwise indicated, all documents cited shall be the latest published versions.

## 4 Terminology

4.1 *Definitions*

4.1.1 *bilateral datum plane* — a vertical plane that bisects the wafers and that is perpendicular to both the horizontal and facial datum planes (as defined in SEMI E57).

4.1.2 *box* — a protective portable container for a cassette and/or substrate(s).

1 International Organization for Standardization, ISO Central Secretariat, 1, rue de Varembé, Case postale 56, CH-1211 Geneva 20, Switzerland. Telephone: 41.22.749.01.11; Fax: 41.22.733.34.30 Website: www.iso.ch

4.1.3 *carrier capacity* — the number of substrates that a carrier holds (as defined in SEMI E1.9).

4.1.4 *cassette* — an open structure that holds one or more substrates.

4.1.5 *door seal zone* — a surface on the exterior side of the port door for sealing to the box door.

4.1.6 *facial datum plane* — a vertical plane that bisects the wafers and that is parallel to the front side of the carrier (where wafers are removed or inserted). On tool load ports, it is also parallel to the load face plane specified in SEMI E15 on the side of the tool where the carrier is loaded and unloaded (as defined in SEMI E57).

4.1.7 *frame seal zone* — a surface on the exterior side of the frame of the port door for sealing to the frame of the box door.

4.1.8 *horizontal datum plane* — a horizontal plane from which projects the kinematic-coupling pins on which the carrier sits. On tool load ports, it is at the load height specified in SEMI E15 and might not be physically realized as a surface (as defined in SEMI E57).

4.1.9 *load face plane* — the furthest physical vertical boundary plane from the cassette centroid or carrier centroid on the side (or sides) of the tool where loading of the tool is intended (as defined in SEMI E15).

4.1.10 *minienvironment* — a localized environment created by an enclosure to isolate the product from contamination and people.

4.1.11 *pod* — a box having a Standard Mechanical Interface (SMIF) per SEMI E19.

4.1.12 *wafer carrier* — any cassette, box, pod, or boat that contains wafers (as defined in SEMI E15).

## 5 Requirements

5.1 *Datum Planes* — The physical alignment mechanism from the box to the tool load port consists of features (not specified in this standard) on the box that mate with three or six pins underneath as defined in SEMI E57. Most of the dimensions of the interface from the box to the tool load port are determined with respect to the three orthogonal datum planes defined in that standard: the horizontal datum plane, the facial datum plane, and the bilateral datum plane. However, the dimensions in this standard do not apply when the box is placed on the load port, but rather when the box has been moved horizontally into place against the front-opening interface. Otherwise, the front-opening interface would interfere with the kinematic coupling during loading, and the minimum rear clearance in E15 would be violated.

5.2 *Symmetry* — All of the dimensions for the interface are bilaterally symmetric about the bilateral datum plane and about a plane *z*30 above the horizontal datum plane with the following exceptions (as viewed by a person standing in front of the tool and facing the interface):

- The registration pins are in the lower right and upper left quadrants of the port door.
- Both latch keys turn 90° counter-clockwise from vertical to unlatch the box door from the box.

5.3 *Door Alignment Maintenance Mechanism* — The two registration pins that are used to limit the maximum displacement of the box door while on the port door are shown in Figures 1 and 2 and specified in Table 1. The over-all surface finish of the registration pins must have a final roughness height less than or equal to *r*47. The registration pins are surrounded by reserved space for optional vacuum application.

5.4 *Locking Mechanism* — The box door is locked and unlocked by a set of two 13.5 mm by 5 mm heads on shafts that have a 5 mm diameter. These latch keys must unlatch the box door from the box by rotating counter-clockwise to horizontal and must latch the box door to the box by rotating clockwise to vertical (as viewed by a person standing in front of the tool facing the *interface*). The latch keys must not rotate beyond these limits of the rotation angle $\psi$. To allow seal compression by latches, the torque delivered by the port to turn the latch keys must be at least *f*30. Thus, it is recommended that no box door be designed that needs more torque than this. Figure 3 shows front, side and top views of the latch keys. In addition, convex features on the outer edges of the latch keys (adjacent to the surface defined by *y*36) must have a blend radius of *r*41 to prevent small contact patches with large stresses that might cause wear and particles. Other convex features on the latch keys need only be de-burred and rounded off. The over-all surface finish of the latch keys must have a final roughness height less than or equal to *r*47.

5.5 *Seal Zones* — On the exterior side of the port must be two areas for sealing to the box. The door seal zone must be just inside the rim of the port door in the area between *x*32 and *x*33 from the facial datum plane and between *z*32 and *z*33 from the vertical center line of the port (which is *z*30 above the facial datum plane). Similarly, the frame seal zone must be on the frame of the port door in the area between *x*34 and *x*35 from the facial datum plane and between *z*34 and *z*35 from the vertical center line of the port. The door and its frame must be designed to mate with a front-opening box that conforms to SEMI E47.1. Specifically, the port door and its frame must have surfaces that mate with the seal zones and the reserved spaces for vacuum application (which includes all of the circles bounded by *r*38 except for the holes for the registration pins at the center of each circle). It is recommended that a gap be maintained between mating surfaces on the box and load port (unless the minienvironment is purged with an inert gas, in which case a tight seal is recommended).

5.6 *Inner and Outer Radii* — All required concave features may have a radius of up to *r*45 to allow cleaning and to prevent contaminant build-up. All required convex features may also have a radius of up to *r*46 to prevent small contact patches with large stresses that might cause wear and particles. Note that these limits on the radius of all required features are specified as a maximum (not a minimum) to ensure that the required features are not rounded off too much. The lower bound on the radius is up to the interface supplier. Note also that this radius applies to every required feature unless another radius is called out specifically.

5.7 *Force Between Box and Port* — The force with which the load port holds the box in place against the FIMS interface must be greater than the force with which the load port presses the box door into the box.

5.8 *Force Between Box Door and Box* — The load port must press the box door into the box with a force of *f*34.

5.9 *Door Return Repeatability* — The load port must return the port door to the closed position after opening with a repeatability given by the dimensions *x*37 and *z*37.

5.10 *Force Applied by Latch Keys* — If the load port uses retracting latch keys, once the latch keys have been turned to the position that unlocks the box door from the box ($\psi = 0 \pm 1°$), the force (in a direction perpendicular to the facial datum plane) applied by each latch key to the FOUP door must be no greater than *f*35.

5.11 *Door Accommodation* — The load port must mate completely with the box at the FIMS interface. One method to accomplish this is to have the load port door protrude sufficiently (with some cushioning ability) to meet the FOUP door (however far the FOUP door protrudes within what SEMI E47.1 allows). The load port door (at least on the seal zone plate) must also accommodate variations in angle (with respect to the Facial Datum Plane) of the FOUP door (however much the FOUP door varies in angle within what SEMI E47.1 allows).

## 6 Related Documents

6.1 *SEMI Standards*

SEMI E15.1 — Specification for 300 mm Tool Load Port

SEMI E63 — Mechanical Specification for 300 mm Box Opener/Loader to Tool Standard (BOLTS-M) Interface

SEMI M31 — Provisional Mechanical Specification for Front-Opening Shipping Box Used to Transport and Ship 300 mm Wafers

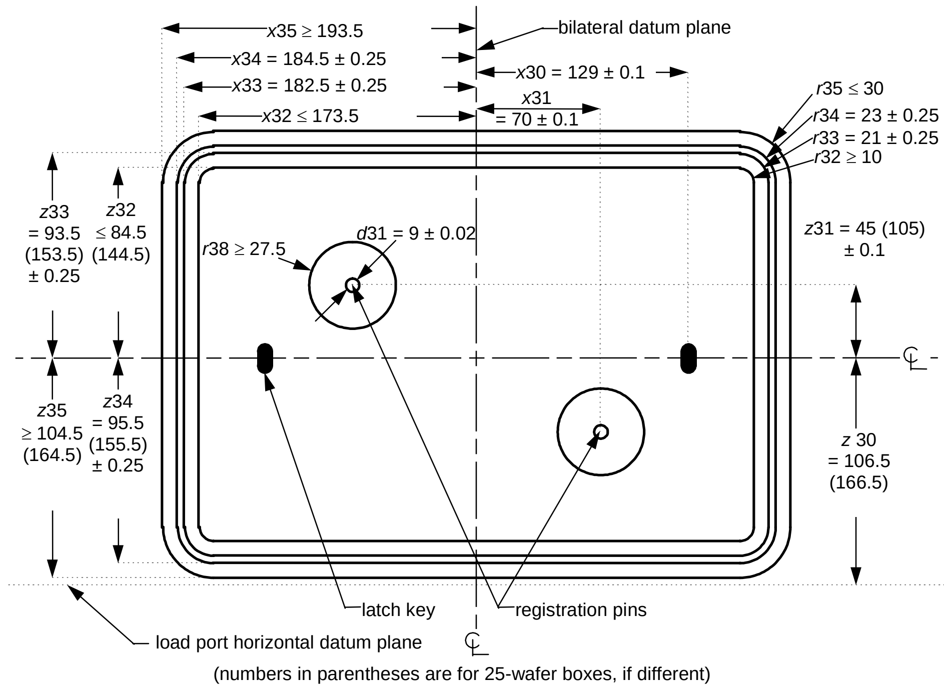


**Figure 1**
**Dimensions for Front-Opening Interface**

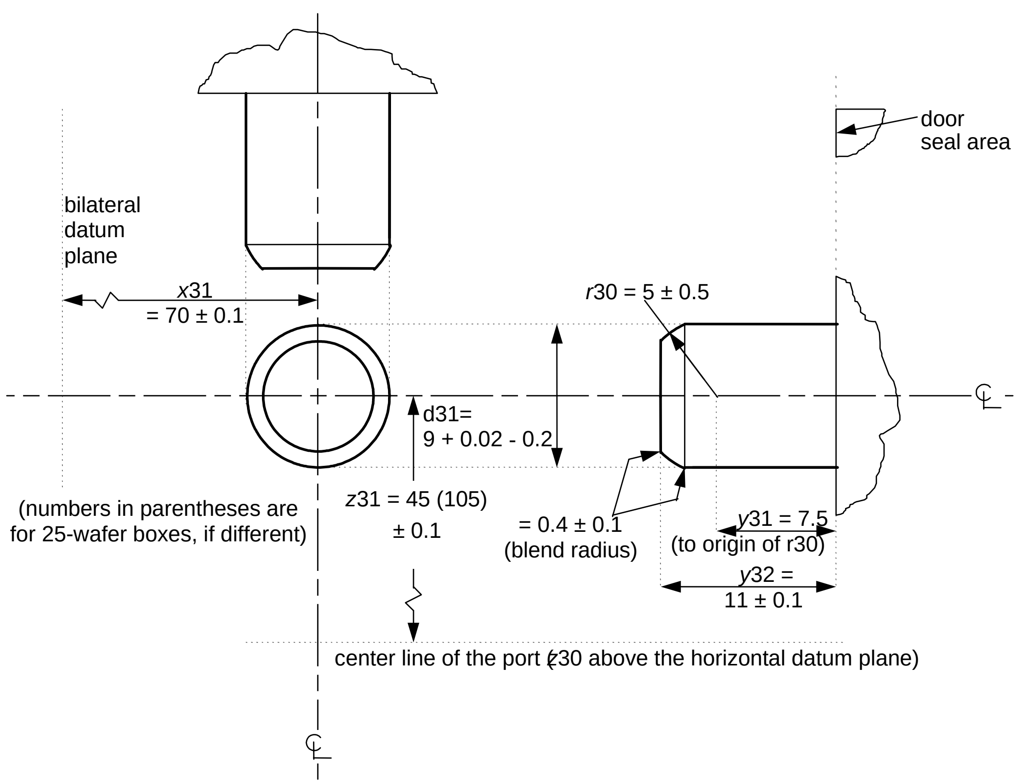


**Figure 2**
**Registration Pin Dimensions**

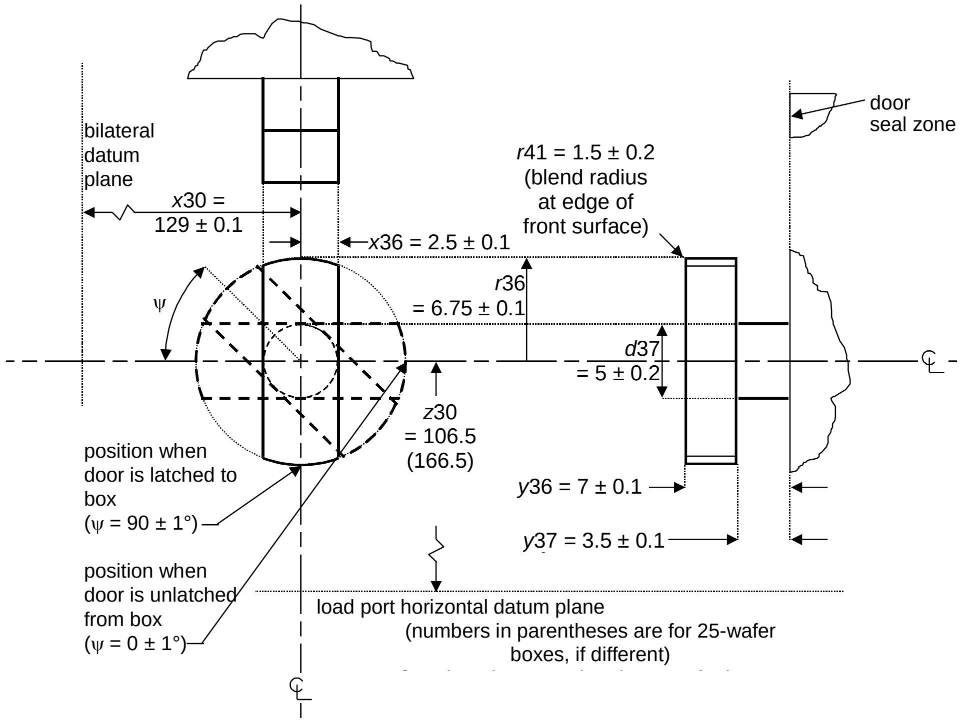


**Figure 3**
**Latch Key Dimensions**

**Table 1 Dimensions for Front-Opening Interface Mechanical Specification (FIMS)**

| *Symbol Used* | *Value Specified* | *Datum Measured from* | *Feature Measured to* |
|---|---|---|---|
| ψ | 0 ± 1° (to unlatch the box door from the box) 90 ± 1° (to latch the box door to the box) | horizontal datum plane | clockwise rotation of latch key |
| *d*31 | 9 + 0.02 mm, −0.2 mm (0.3543 + 0.0008 in. −0.008 in.) | diameter centered on the intersection of *x*31 and *z*31 | surface of registration pin shaft |
| *d*37 | 5 ± 0.2 mm (0.197 ± 0.008 in.) | diameter centered on the intersection of *x*30 and *z*30 | surface of latch key shaft |
| *f*30 | 1.7 N-m (15 in.-lbf.) minimum | not applicable | torque delivered by the port to turn the latch keys |
| *f*34 | 9 N (2 lbf.) minimum | not applicable | force with which the port presses the box door into the box |
| *f*35 | 20 N (4.5 lbf.) maximum | not applicable | force per latch key applied to the FOUP door (in a direction perpendicular to the facial datum plane) |
| *r*30 | 5 ± 0.5 mm (0.20 ± 0.02 in.) | intersection of *x*31, *y*31, and *z*31 | shoulder of registration pin |
| *r*32 | 10 mm (0.39 in.) minimum | not applicable | inside corner of door seal zone |
| *r*33 | 21 ± 0.25 mm (0.827 ± 0.010 in.) | not applicable | outside corner of door seal zone |
| *r*34 | 23 ± 0.25 mm (0.906 ± 0.010 in.) | not applicable | inside corner of frame seal zone |

| *Symbol Used* | *Value Specified* | *Datum Measured from* | *Feature Measured to* |
|---|---|---|---|
| *r*35 | 30 mm (1.18 in.) maximum | not applicable | outside corner of frame seal zone |
| *r*36 | 6.75 ± 0.1 mm (0.266 ± 0.004 in.) | intersection of *x*30 and *z*30 | ends of latch key head |
| *r*38 | 27.5 mm (1.08 in.) minimum | intersection of *x*31 and *z*31 | boundary of vacuum application zone around registration pin |
| *r*40 | 0.4 ± 0.1 mm (0.016 ± 0.004 in.) | not applicable | blend at intersection of *r*30 with *r*31 and *y*32 |
| *r*41 | 1.5 ± 0.2 mm (0.059 ± 0.008 in.) | not applicable | blend at convex features on the outer edge of the latch keys (adjacent to the surface defined by *y*36) |
| *r*45 | 1 mm (0.04 in.) maximum | not applicable | all concave features (radius) |
| *r*46 | 2 mm (0.08 in.) maximum | not applicable | all required convex features (radius) |
| *r*47 | 0.80 µm (32 µin.) maximum Roughness ($R_a$) as defined in ISO 4287 | not applicable | surface finish of the registration pins and latch keys |
| *x*30 | 129 ± 0.1 mm (5.08 ± 0.004 in.) | bilateral datum plane | center line of latch key rotation |
| *x*31 | 70 ± 0.1 mm (2.756 ± 0.004 in.) | bilateral datum plane | center of registration pins |
| *x*32 | 173.5 mm (6.83 in.) maximum | bilateral datum plane | inside edge of door seal zone |
| *x*33 | 182.5 ± 0.25 mm (7.185 ± 0.010 in.) | bilateral datum plane | outside edge of door seal zone |
| *x*34 | 184.5 ± 0.25 mm (7.264 ± 0.010 in.) | bilateral datum plane | inside edge of frame seal zone |
| *x*35 | 193.5 mm (7.62 in.) minimum | bilateral datum plane | outside edge of frame seal zone |
| *x*36 | 2.5 ± 0.1 mm (0.098 ± 0.004 in.) | *x*30 from bilateral datum plane | side of latch key head |
| *x*37 | ± 0.2 mm (± 0.008 in.) | position of the load port door before opening | position of the load port door after closing |
| *y*31 | 7.5 mm (0.30 in.) | point on door seal zone closest to facial datum plane | origin of *r*30 (shoulder radius) on registration pin |
| *y*32 | 11.0 ± 0.1 mm (0.43 ± 0.004 in.) | point on door seal zone closest to facial datum plane | end of registration pin |
| *y*36 | 7.0 ± 0.1 mm (0.28 ± 0.004 in.) | point on door seal zone closest to facial datum plane | far side of latch key head |
| *y*37 | 3.5 ± 0.1 mm (0.14 ± 0.004 in.) | point on door seal zone closest to facial datum plane | near side of latch key head |
| *z*30 | 106.5 ± 0 mm (4.19 ± 0 in.) for 13-wafer cassette and 166.5 ± 0 mm (6.56 ± 0 in.) for 25-wafer cassette | horizontal datum plane | vertical center line of port and center line of latch key rotation |
| *z*31 | 45 ± 0.1 mm (1.772 ± 0.004 in.) for 13-wafer cassette and 105 ± 0.1 mm (4.134 ± 0.004 in.) for 25-wafer cassette | *z*30 above horizontal datum plane | center of registration pins |

| *Symbol Used* | *Value Specified* | *Datum Measured from* | *Feature Measured to* |
|---|---|---|---|
| *z*32 | 84.5 mm (3.33 in.) maximum for 13-wafer cassette and 144.5 mm (5.69 in.) maximum for 25-wafer cassette | *z*30 above horizontal datum plane | inside edge of door seal zone |
| *z*33 | 93.5 ± 0.25 mm (3.681 ± 0.010 in.) for 13-wafer cassette and 153.5 ± 0.25 mm (6.043 ± 0.010 in.) for 25-wafer cassette | *z*30 above horizontal datum plane | outside edge of door seal zone |
| *z*34 | 95.5 ± 0.25 mm (3.760 ± 0.010 in.) for 13-wafer cassette and 155.5 ± 0.25 mm (6.122 ± 0.010 in.) for 25-wafer cassette | *z*30 above horizontal datum plane | inside edge of frame seal zone |
| *z*35 | 104.5 mm (4.11 in.) minimum for 13-wafer cassette and 164.5 mm (6.48 in.) minimum for 25-wafer cassette | *z*30 above horizontal datum plane | outside edge of frame seal zone |
| *z*37 | ± 0.2 mm (± 0.008 in.) | position of the load port door before opening | position of the load port door after closing |

# APPENDIX 1
# APPLICATION NOTES

**NOTICE**: This appendix was approved as an official part of SEMI E62, but the recommendations in this appendix are optional and are not required to conform to this standard.

A1-1 Perpendicularity and parallelism are implicitly defined in the geometric tolerances.

A1-2 ¶6.1 discusses the need for clearance between the box and the tool's front-opening interface when the box is placed on the load port. After the box is placed on the load port, the kinematic couplings will move the box forward to engage with the tool's front-opening interface. The possibility of human fingers being pinched between the box and the tool's front-opening interface may be a safety concern for tool designers.

# SEMI E63-1104
# MECHANICAL SPECIFICATION FOR 300 mm BOX OPENER/LOADER TO TOOL STANDARD (BOLTS-M) INTERFACE

This specification was technically approved by the Global Physical Interfaces & Carriers Committee and is the direct responsibility of the North American Physical Interfaces & Carriers Committee. Current edition approved by the North American Regional Standards Committee on July 11, 2004 and August 16, 2004. Initially available at www.semi.org September 2004; to be published November 2004. Originally published in 1997, previously published June 2000.

## 1 Purpose

1.1 This standard specifies the tool side of the mechanical interface between the main part of a process or metrology tool and the component that opens boxes and presents the boxes to the tool wafer handler for unloading and loading 300 mm wafers. The box opener/loader unit would include one or more load ports (that would conform to SEMI E15.1) as well as storage capacity for empty boxes or waiting lots (if needed by the tool throughput). The box opener/loader unit might not only be configured to handle boxes (that would conform to SEMI E47.1 and SEMI E62) but also to open cassettes (that would conform to SEMI E1.9). This standard defines one interface for all such carriers and for any carrier capacity (13 and 25 wafers).

## 2 Scope

2.1 This standard is intended to set an appropriate level of specification that places minimal limits on innovation while ensuring modularity and interchangeability at all mechanical interfaces. Only the mechanical interface is specified; no materials requirements or micro-contamination limits are given. The interface specified in this standard is designed for a tool with a sealed minienvironment, but it could also just be a well-defined automation interface. This interface is not intended to provide high repeatability or rapid removal (both of which can be provided by other couplings in the box opener/loader unit). This specification also does not apply when load ports are stacked one on top of the other. This specification does not apply when inserting open cassettes into load-lock chambers directly.

**NOTICE:** This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory or other limitations prior to use.

## 3 Referenced Standards

3.1 *SEMI Standards*

SEMI E1.9 — Mechanical Specification for Cassettes Used to Transport and Store 300 mm Wafers

SEMI E15 — Specification for Tool Load Port

SEMI E15.1 — Specification for 300 mm Tool Load Port

SEMI E19 — Standard Mechanical Interface (SMIF)

SEMI E47.1 — Provisional Mechanical Specification for Boxes and Pods Used to Transport and Store 300 mm Wafers

SEMI E57 — Mechanical Specification for Kinematic Couplings Used to Align and Support 300 mm Wafer Carriers

SEMI E62 — Provisional Specification for 300 mm Front-Opening Interface Mechanical Standard (FIMS)

3.2 *ISO Specification* [1]

ISO/DIS 68-1 — ISO General Purpose Screw Threads – Basic Profile – Part I: Metric Screw Threads

**NOTICE:** Unless otherwise indicated, all documents cited shall be the latest published versions.

## 4 Terminology

4.1 *Definitions*

4.1.1 *bilateral datum plane* — a vertical plane that bisects the wafers and that is perpendicular to both the horizontal and facial datum planes (as defined in SEMI E57).

4.1.2 *BOLTS plane* — a plane parallel to the facial datum plane near the front of the tool where the box opener/loader is attached.

1 International Organization for Standardization,ISO Central Secretariat, 1, rue de Varembé, Case postale 56, CH-1211 Geneva 20, Switzerland. Telephone: 41.22.749.01.11; Fax: 41.22.733.34.30, Website: /www.iso.ch

4.1.3 *box* — a protective portable container for a cassette and/or substrate(s).

4.1.4 *box opener/loader* — the equipment component that opens wafer carriers (if needed) and presents the carriers to the equipment's wafer handler for unloading and loading wafers.

4.1.5 *carrier capacity* — the number of substrates that a carrier holds (as defined in SEMI E1.9).

4.1.6 *cassette* — an open structure that holds one or more substrates.

4.1.7 *equipment front end module (EFEM)* — consists of the carrier handler that receives carriers from the factory material handling system on one or more load ports (as specified in SEMI E15.1), opens the carriers (if needed), and may include a substrate handler for unloading and loading wafers from the carrier to the process part of the equipment.

4.1.8 *facial datum plane* — a vertical plane that bisects the wafers and that is parallel to the front side of the carrier (where wafers are removed or inserted). On tool load ports, it is also parallel to the load face plane specified in SEMI E15 on the side of the tool where the carrier is loaded and unloaded (as defined in SEMI E57).

4.1.9 *horizontal datum plane* — a horizontal plane from which project the kinematic-coupling pins on which the carrier sits. On tool load ports, it is at the load height specified in SEMI E15 and might not be physically realized as a surface (as defined in SEMI E57).

4.1.10 *load face plane* — the furthest physical vertical boundary plane from the cassette centroid or carrier centroid on the side (or sides) of the tool where loading of the tool is intended (as defined in SEMI E15).

4.1.11 *minienvironment* — a localized environment created by an enclosure to isolate the product from contamination and people.

4.1.12 *pod* — a box having a Standard Mechanical Interface (SMIF) per SEMI E19.

4.1.13 *seal zone* — a surface on the tool at the BOLTS plane for sealing to the box opener/loader.

4.1.14 *wafer carrier* — any cassette, box, pod, or boat that contains wafers (as defined in SEMI E15).

## 5 Requirements

5.1 *Datum Planes* — The physical alignment mechanism for the box consists of features (not specified in this standard) on the box that mate with three or six pins underneath as defined in SEMI E57. Many of the dimensions of the BOLTS interface are determined with respect to the three orthogonal datum planes defined in that standard: the horizontal datum plane, the facial datum plane, and the bilateral datum plane. The BOLTS plane is defined to be parallel to and at a distance *y*70 from the facial datum plane of the carrier (when the carrier is docked and in position for wafer extraction and insertion). If the carrier is rotated after being placed on the loadport, the facial datum plane of the carrier and the BOLTS plane may no longer be parallel to the load face plane of the equipment. If the carrier is not rotated, the distance (called the docking stroke) between the facial datum plane when the carrier is placed on the loadport (undocked) and the facial datum plane when the carrier is in position for wafer extraction and insertion (docked) must be *y*76 (but this is only a requirement for equipment delivered in the year 2000 or later). The tolerance on *y*70 is the installation tolerance. The cycle-to-cycle repeatability on *y*70 (without replacing the box opener/loader unit) must be within *y*75.

5.2 *Symmetry* — All of the dimensions for the interface are bilaterally symmetric about the bilateral datum plane. These dimensions are shown in Figure 1 and specified in Table 1.

5.3 *Hole Opening* — The BOLTS interface consists of a hole in the front of the tool at the BOLTS plane, a seal zone surrounding the hole, six threaded holes for bolting on the box opener/loader, reserved spaces for the box opener/loader inside the tool from the hole, and an exclusion volume for the box opener/loader outside of the hole. The dimensions of the hole are defined by *x*71, *z*71, and *z*76.

5.4 *Seal Zone* — On the BOLTS plane surrounding the hole opening must be a flat area for sealing between the tool and the box opener/loader. The inner dimensions of the seal zone are the same as the hole opening, and the outer dimensions of the seal zone are defined by *x*72, *z*72, and *z*77. The flatness of the seal zone must be within *y*71, and the perpendicularity of the seal zone to the facial and horizontal datum planes must be within $\sigma$.

5.5 *Bolt Holes* — At six points on the BOLTS plane there must be threaded holes for bolting on the box opener/loader. The opening of the threaded holes must be within the flatness of the seal zone (*y*71), and the holes must be at least *y*73 deep. The internal threads must conform to the ISO/DIS 68-1 specification which has a nominal diameter of 8 mm (0.31 in.), a thread pitch of 1.25 mm (0.05 in.), a normal length of engagement from 4 to 12 mm (0.16 to 0.47 in.), and no allowance (variation from basic diameter). The centers of the threaded holes are to be located at *x*73 to the left and right of the bilateral datum plane, and centers of the top, middle, and bottom pairs of threaded holes are to be located at *z*78 above, *z*75 below, and *z*73 below the horizontal datum plane, respectively. Not all of these bolt holes need to be used by every box opener/loader, but all six threaded holes must be present on the tool. Note that the middle pair of threaded holes is in the seal zone, and so it may be covered up by some gaskets (which are not specified here).

5.6 *Reserved Spaces* — Inside the tool from the BOLTS plane are volumes reserved for the box opener/loader into which tool and its wafer handler may not protrude. A permanent reserved space is bounded by *x*70, *y*74, *z*70, and *z*80. When the door is closed, there is an additional temporary reserved space bounded by *x*70, *y*72, and *z*81. When the door is being opened or closed by the box opener/loader, there is a further temporary reserved space bounded by *x*70, *y*74, and *z*81. When the door is fully open, it will be withdrawn into the permanent reserved space, and the tool wafer handler may extend into the box to extract or insert wafers.

5.7 *Exclusion Volume* — Outside the tool from the BOLTS plane is a volume reserved for the box opener/loader into which the exterior of the tool may not protrude. This exclusion volume is bounded by *x*74, *z*79, and the floor. Within these boundaries and outside of the seal zone, no part of the tool may protrude closer to the facial datum plane than the closest point of the seal zone. Also, it is recommended that no part of the tool should overhang the box opener/loader, even above *z*79. Note that *x*74 has been chosen to allow the minimum width between adjacent load ports defined in SEMI E15.1.

5.8 *Inner and Outer Radii* — All required concave features may have a radius of up to *r*75 to allow cleaning and to prevent contaminant build-up. All required convex features may also have a radius of up to *r*76 to prevent small contact patches with large stresses that might cause wear and particles. Note that these limits on the radius of all required features are specified as a maximum (not a minimum) to ensure that the required features are not rounded-off too much. The lower bound on the radius is up to the tool supplier. Note also that this radius applies to every required feature unless another radius is called out specifically.

## 6 Related Documents

6.1 *SEMI Standards*

SEMI M31 — Provisional Mechanical Specification for Front-Opening Shipping Box Used to Transport and Ship 300 mm Wafers

SEMI E84 — Specification for Enhanced Carrier Handoff Parallel I/O Interface

**NOTICE:** Unless otherwise indicated, all documents cited shall be the latest published versions.

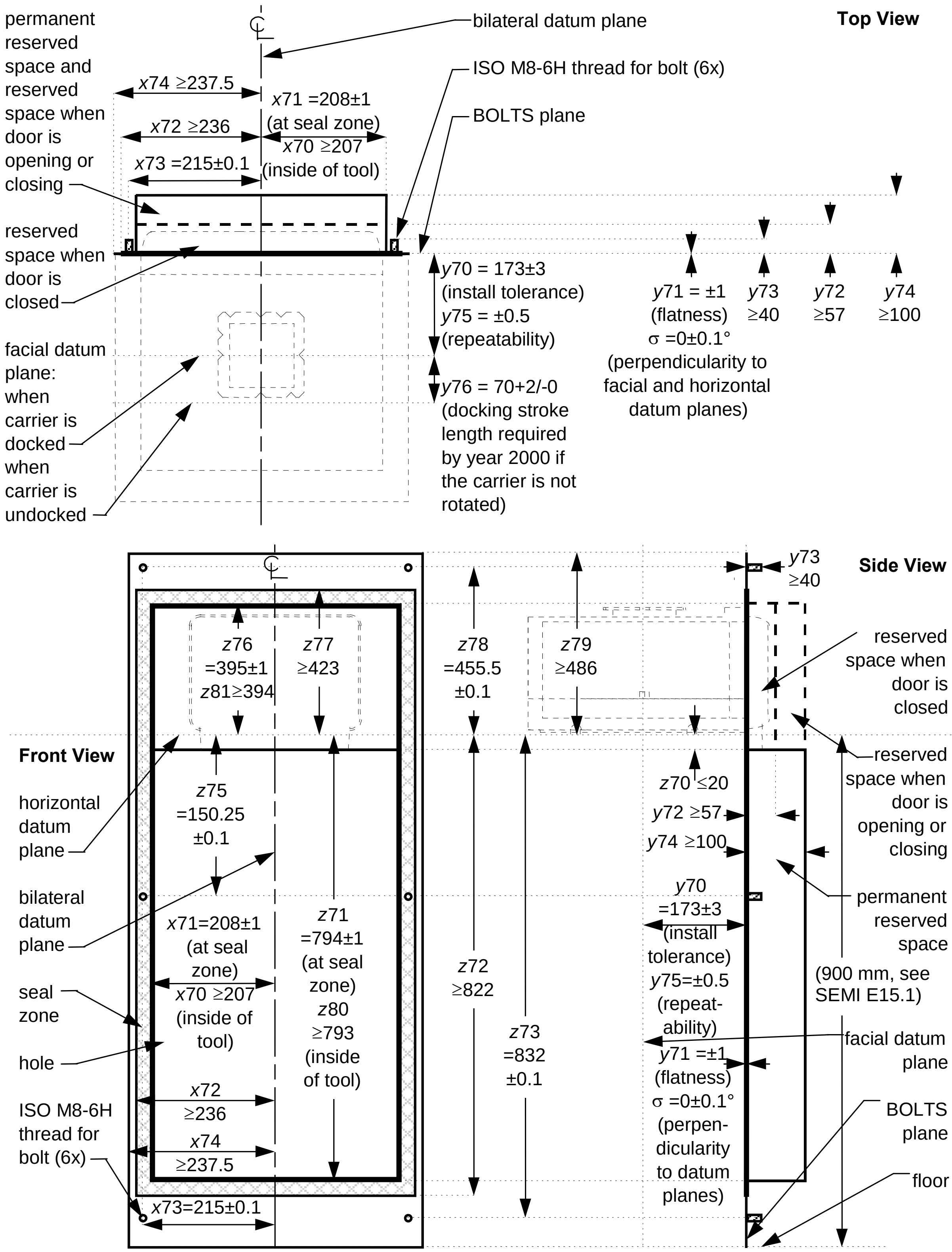


**Figure 1**
**Top, Front, and Side Views of Box Opener/Loader to Tool Standard (BOLTS) Interface**

**Table 1 Dimensions for Box Opener/Loader to Tool Standard (BOLTS) Interface**

| *Symbol* | *Value Specified* | *Datum Measured from* | *Feature Measured to* |
|---|---|---|---|
| σ | 0 ± 0.1° | facial and horizontal datum planes | perpendicularity of seal zone |
| *r*75 | 1 mm (0.04 in.) maximum | not applicable | all concave features (radius) |
| *r*76 | 2 mm (0.08 in.) maximum | not applicable | all required convex features (radius) |
| *x*70 | 207 mm (8.15 in.) minimum | bilateral datum plane | encroachment of tool on the sides of the reserved spaces inside the tool |
| *x*71 | 208 ± 1 mm (8.19 ± 0.04 in.) | bilateral datum plane | edge of hole opening and inside edge of seal zone |
| *x*72 | 236 mm (9.29 in.) minimum | bilateral datum plane | outside edge of seal zone |
| *x*73 | 215 ± 0.1 mm (8.465 ± 0.004 in.) | bilateral datum plane | center of threaded holes |
| *x*74 | 237.5 mm (9.35 in.) minimum | bilateral datum plane | encroachment of tool on the sides of the box opener/loader outside of the BOLTS plane |
| *y*70 | 173 ± 3 mm (6.8 ± 0.1 in.) | facial datum plane (when carrier is docked) | BOLTS plane (including seal zone and boundaries of equipment exclusion zones) installation tolerance |
| *y*71 | ± 1 mm (± 0.04 in.) flatness over seal zone | BOLTS plane | surface of seal zone |
| *y*72 | 57 mm (2.24 in.) minimum | BOLTS plane | encroachment of tool on the reserved space inside the tool when the door is closed |
| *y*73 | 40 mm (1.57 in.) minimum | BOLTS plane | depth of threaded holes |
| *y*74 | 100 mm (3.94 in.) minimum | BOLTS plane | encroachment of tool on the permanent reserved space and on the reserved space when the door is opening or closing |
| *y*75 | ± 0.5 mm (± 0.02 in.) | not applicable | the docked facial datum plane of the box opener/loader |
| *y*76 | 70 +2 –0 mm (2.76 +0.07 –0 in.) | facial datum plane when the carrier is undocked | facial datum plane when the carrier is docked |
| *z*70 | 20 mm (0.79 in.) maximum | horizontal datum plane | encroachment of tool on the top of the permanent reserved space inside the tool |
| *z*71 | 794 ± 1 mm (31.26 ± 0.04 in.) | horizontal datum plane | bottom edge of hole opening and inside edge of seal zone |
| *z*72 | 822 mm (32.36 in.) minimum | horizontal datum plane | outside edge of seal zone on bottom |
| *z*73 | 832 ± 0.1 mm (32.756 ± 0.004 in.) | horizontal datum plane | center of bottom threaded holes |
| *z*75 | 150.25 ± 0.1 mm (5.915 ± 0.004 in.) | horizontal datum plane | center of middle threaded holes |
| *z*76 | 395 ± 1 mm (15.55 ± 0.04 in.) | horizontal datum plane | top edge of hole opening and inside edge of seal zone |
| *z*77 | 423 mm (16.65 in.) minimum | horizontal datum plane | outside edge of seal zone on top |
| *z*78 | 455.5 ± 0.1 mm (17.933 ± 0.004 in.) | horizontal datum plane | center of top threaded holes |
| *z*79 | 486 mm (19.13 in.) minimum | horizontal datum plane | encroachment of tool on the top of the box opener/loader between the BOLTS plane and the load face plane |
| *z*80 | 793 mm (31.22 in.) minimum | horizontal datum plane | encroachment of tool on the bottom of the permanent reserved space inside the tool |
| *z*81 | 394 mm (15.51 in.) minimum | horizontal datum plane | encroachment of tool on the top of the reserved space inside the tool when the door is closed or is opening or closing |

# RELATED INFORMATION 1
# APPLICATION NOTES

**NOTICE**: This related information is not an official part of SEMI E63 but was approved for publication by full letter ballot procedures.

R1-1  Unless otherwise stated, perpendicularity and parallelism are implicitly defined in the geometric tolerances.

# SEMI E64-0600 (Reapproved 0305)
# SPECIFICATION FOR 300 mm CART TO SEMI E15.1 DOCKING INTERFACE PORT

This specification was technically reapproved by the Global Physical Interfaces & Carriers Committee and is the direct responsibility of the North American Physical Interfaces & Carriers Committee. Current edition approved by the North American Regional Standards Committee on December 10, 2004. Initially available at www.semi.org February 2005; to be published March 2005. Originally published in 1997; previously published June 2000.

## 1 Purpose

1.1 This specification defines a standard location on SEMI E15.1-compliant tools and requirements to be used for installing a docking interface for carrier transport carts. It is intended to promote a consistent interface location between carrier transport carts and SEMI E15.1-compliant wafer process or inspection equipment.

## 2 Scope

2.1 This standard covers 300 mm SEMI E15.1-compliant tools only. Similar requirements for other tools are not defined here.

2.2 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

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## 3 Limitations

3.1 This standard does not define interface functionality, lead-in, accuracy, carrier transfer, compliance, impact, or vibration restrictions. Cart and docking interface designs should comprehend physical limitations of tools to which they are being applied.

## 4 Referenced Standards

4.1 *SEMI Standards*

SEMI E15 — Specification for Tool Load Port

SEMI E15.1 — Specification for 300 mm Tool Load Port

SEMI E23 — Specification for Cassette Transfer Parallel I/O Interface

**NOTICE:** Unless otherwise indicated, all documents cited shall be the latest published versions.

## 5 Terminology

5.1 *Definitions*

5.1.1 *automatic docking* — contact motion is controlled or limited by the design of the cart or interface.

5.1.2 *carrier* — any cassette, box, pod, or boat that contains wafers (per SEMI E15).

5.1.3 *cart* — a floor-based carrier transfer vehicle.

5.1.4 *docking* — the act of locating a floor-based carrier transport vehicle for carrier transfer to/from equipment.

5.1.5 *load face plane* — the furthest physical vertical boundary plane from carrier centroid on the side(s) of the equipment where loading of the tool is intended (per SEMI E15).

5.1.6 *load port* — the interface location on a tool where carriers are placed to allow the tool to process wafers (per SEMI E15).

5.1.7 *manual docking* — contact motion controlled by the operator of the cart.

5.1.8 *transfer* — to either load or unload (per SEMI E15).

## 6 Requirements

6.1 The following exclusion volume is reserved on SEMI E15.1-compliant tools for the installation of a docking interface device. This volume is referred to as Zone L.

6.1.1 *Interface Zone L* — A volume, just above floor level, reserved in SEMI E15.1 for installation of a contact docking device.

6.1.1.1 The vertical bounds of Zone L are defined by the floor from which Dimension H is measured in SEMI E15.1 and the Height $L_h$, per Table 1.

6.1.1.2 The depth of Zone L into the tool is $L_d$, measured from the load face plane as defined in SEMI E15.1.

6.1.1.3 The width of Zone L, $L_w$, is the full width of the tool measured at the load face plane.

6.1.1.4 A device mounted in Zone L is to be physically isolated from the tool and should be mounted such that the tool and tool load port are protected from the impact incurred during docking.

6.1.1.5 Since docking devices must be mounted on the floor in Zone L, the equipment must not require the use of support pedestals or other support structures under the floor below Zone L.

**Table 1 Dimensional Requirements for Docking Zone L**

| *Dimension* | *Value, mm (in.)* |
|---|---|
| Zone L depth, $L_d$ | 100 (3.9) |
| Zone L width, $L_w$ | Width of tool |
| Zone L height, $L_h$ | 100 (3.9) |

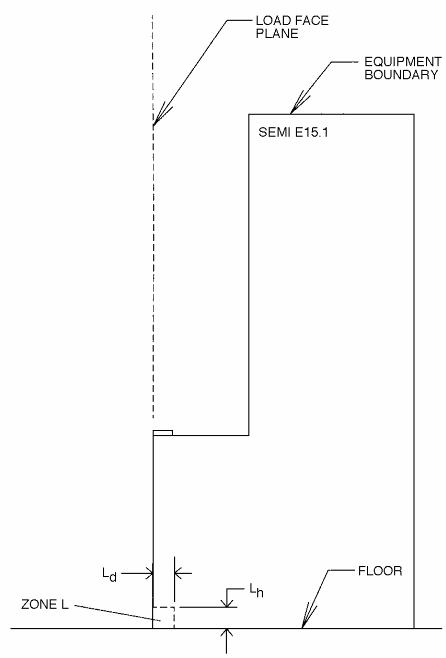


**Figure 1**
**Side Elevation View**

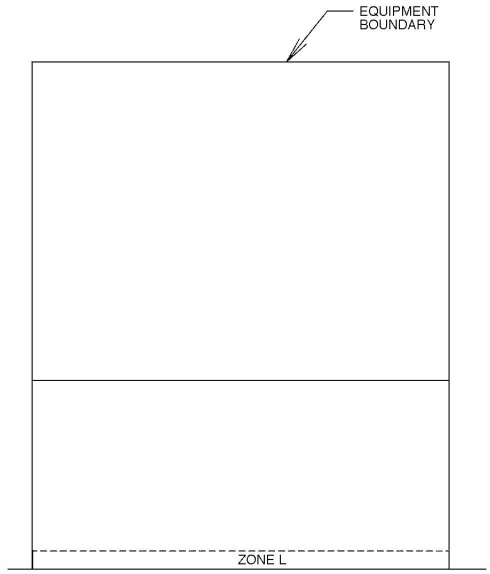


**Figure 2**
**Front Elevation View**

# RELATED INFORMATION 1
# APPLICATION NOTES

**NOTICE**: This related information is not an official part of SEMI E64 but was approved for publication by full letter ballot procedures.

R1-1 The intent of this standard is (1) To provide manually guided 300 mm carrier transport carts a standard location for docking to process and other tools; and (2) To facilitate development of a rapid repeatable cart to load port carrier transfer method or mechanism. Standardization of the size and location will allow for a modularity of the docking interface while minimizing limits on functionality of the interface.

R1-2 Zone L is defined as an exclusion zone in tools that comply with SEMI E15.1. It is intended that the tool side of a “cart/tool” docking interface be mounted in this zone.

R1-3 The docking interface (cart or tool side) may include all or some of the following features/functionality:

- Stopping cart motion,
- Dampening impact of docking,
- Compliance, Lead-in guidance for cart,
- Alignment of cart to docking interface, and
- Securely locking position of cart during carrier transfer.

R1-4 It is likely that the alignment error and tolerance stack-up between a device in Zone L and the tool port will not provide sufficient accuracy alone for accurate pick/placement of a carrier onto the kinematic couplings on the load port.

R1-5 Possible sources of alignment errors are

- Cleanroom floor height and level,
- Cart wheels and framework,
- Installation accuracy of device in Zone L, and
- Stability of mounting (floor changes).

R1-6 It may be necessary to use additional alignment methods to improve accuracy of carrier placement onto the kinematic couplings.

R1-7 It is expected that the interface device will be floor-mounted. SEMI E64 allows for automatic docking but does not specify the means or interfaces required. Cart/interface designers may find it advantageous to add registration features to the tool or load port which facilitate automatic docking and/or carrier transfer.

NOTE 1: Exclusion Zone L partially overlaps the installation space for the photo-coupled interface in SEMI E23. Compliance with both standards is possible. Suppliers should be aware of both standards and design accordingly.

R1-8 Compatibility with SEMI E23 can be maintained by reserving the area just above Zone L for installation of the photo-coupled I/O interface specified in SEMI E23 as shown in Figure R1-1.

R1-9 Zone L should remain clear of any physical obstructions to allow for installation of docking interface devices. End users may require other features that occupy this space, but should be aware that this could limit cart to tool docking solutions.

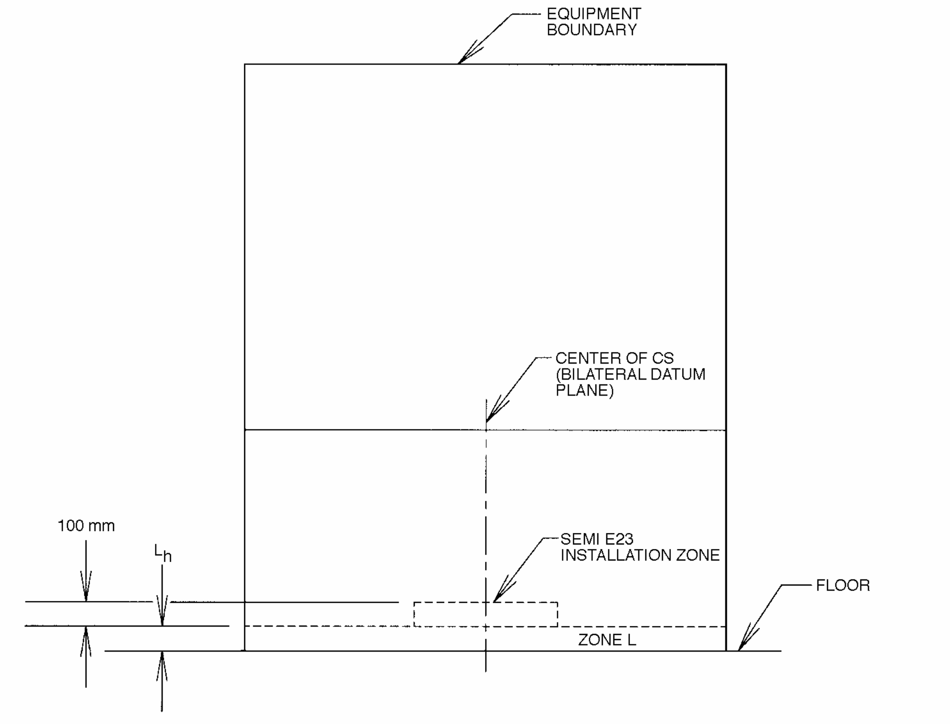


**Figure R1-1**
**Front Elevation View**

R1-10 Note that an installed docking interface may cause a potential trip hazard as shown in Figure R1-2. Equipment suppliers and/or docking interface suppliers may be required to eliminate the potential of this hazard (e.g., by adding covers or shields).

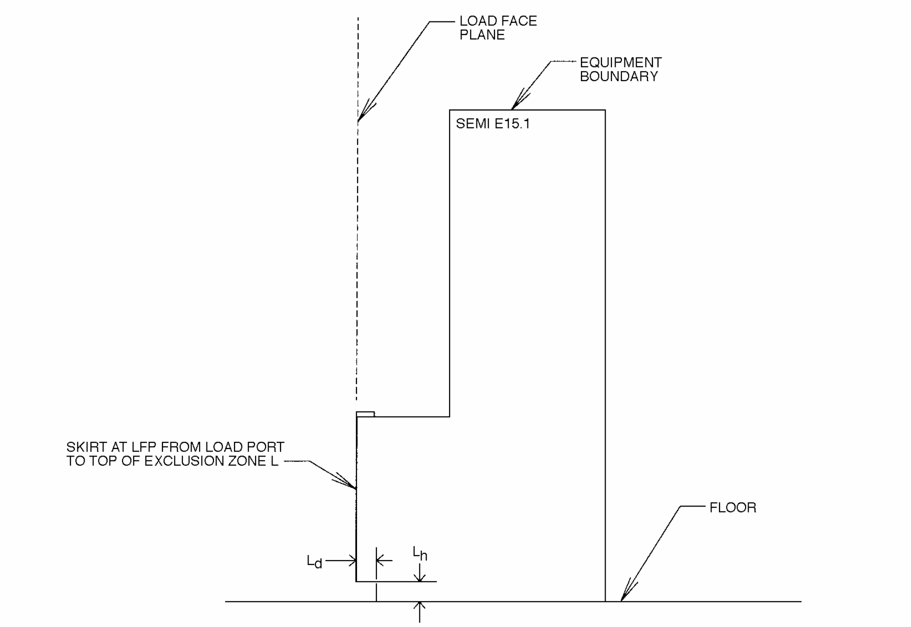


**Figure R1-2**
**Side Elevation View**