The Mask Maker Survey 2017

- **2015: Members requested the eBeam Initiative to restart the survey**
  - A few questions and 8 participating mask makers: AMTC, DNP, GLOBALFOUNDRIES, HOYA, Photronics, Samsung, SMIC and Toppan
  - Thanks to David Powell, Inc. for their continued work
- **2016: More questions and more mask makers added**
  - AMTC, DNP, GLOBALFOUNDRIES, HOYA, Intel, PDMC, Photronics, Samsung, SMIC and Toppan participated; thanks to Brian Grenon as an advisor
- **2017: Thank you to the 10 participating mask makers**
  - AMTC, DNP, GLOBALFOUNDRIES, Intel, PDMC, Photronics, Samsung, SMIC, TMC and Toppan
  - ~118% increase in masks reported => year-to-year comparisons need some care
  - Collected data are "for the last 12 months (July 2016 to June 2017)"

463,792 Masks Delivered by 10 Companies
2017: Q3 2016 – Q2 2017   2016: total reported was 212,956

Masks Delivered by Ground Rule
2016 vs 2017

Masks Delivered by Ground Rule < 45nm
2016 vs 2017
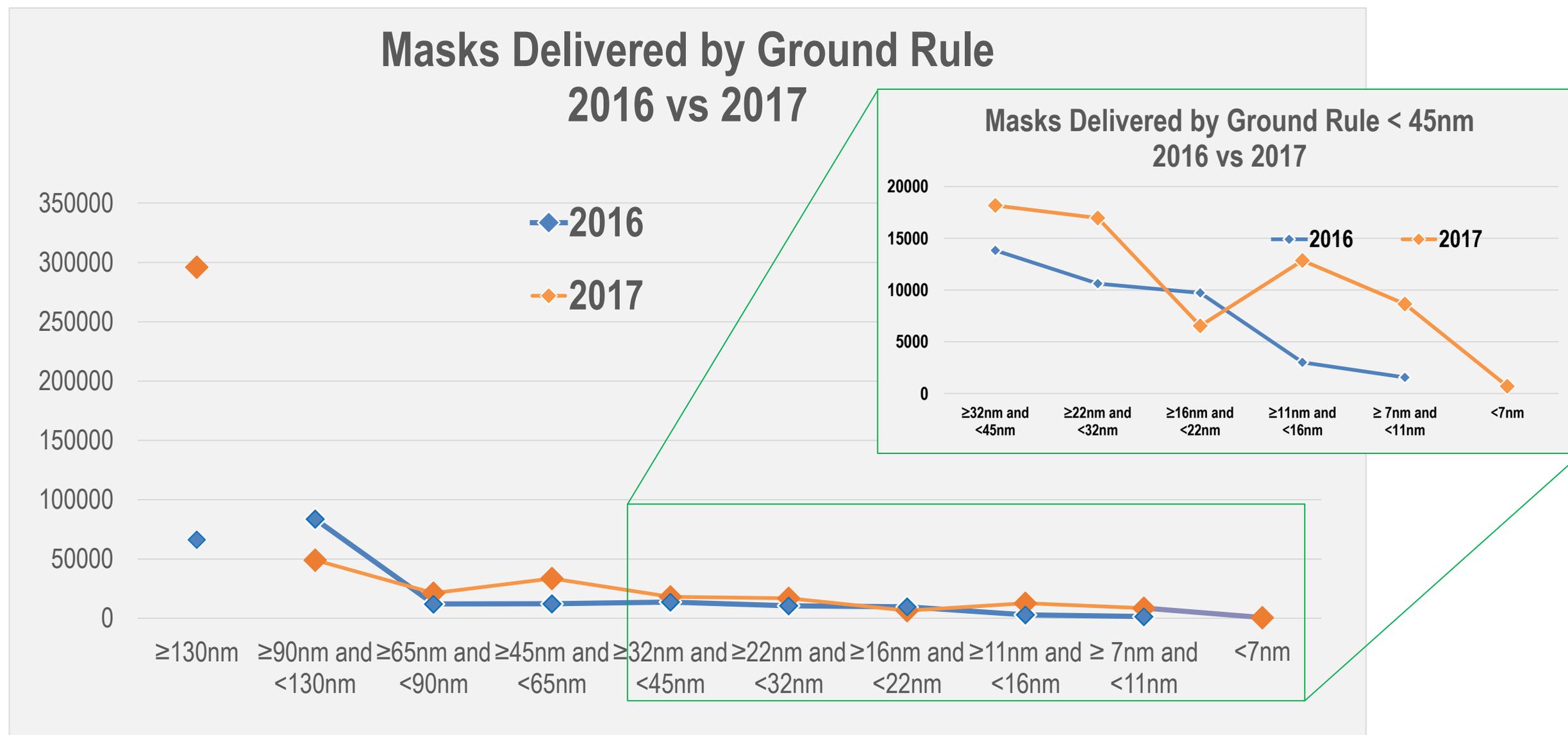
Q: What was the number of masks delivered?
Q: Percent of the total number of masks in the preceding question by Ground Rules?

1041 EUV Masks Reported in 2017 Survey
Versus 382 EUV Masks in 2016 Survey

Masks Delivered by Type
2017 (n=10)

- AltPSM, 0.4%
- Other, 1.5%
- EUV, 0.2%
- AttPSM, 13.8%
- Binary, 84.2%

Masks Delivered by Substrate
2017 (n=10)

- EUV, 0.2%
- Other, 1.5%
- MoSION AttPSM, 12.6%
- OMOG, 2.6%
- Chromium, 83.2%
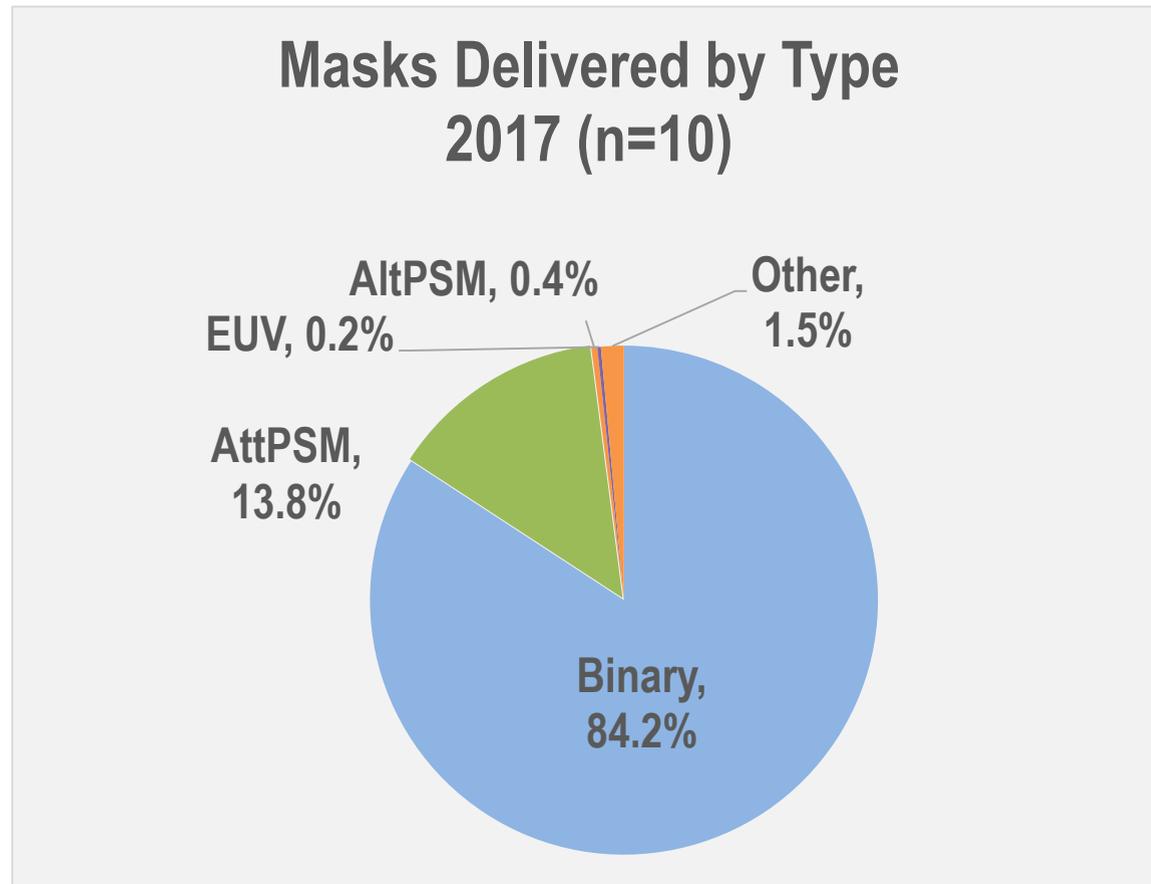
Q: What was the % by…?
Binary, AttPSM, AltPSM, EUV, Other
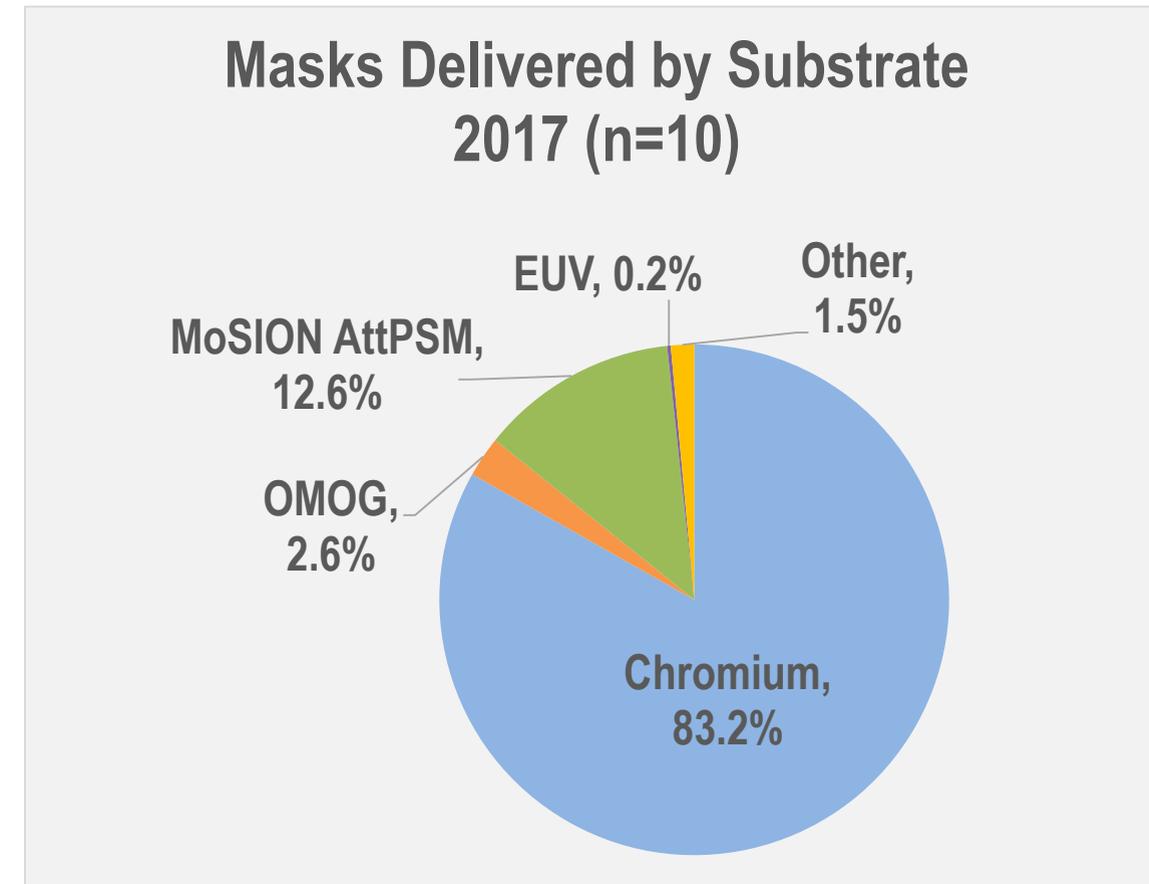
Q: What was the % by substrate type?
Chromium, OMOG, MoSION AttPSM, EUV, Other

eBeam Pattern Generation Used on ~29%
2017 Survey Participants Didn't Report Any Multi-beam Masks Yet

Masks Delivered by Pattern Generation 2017 (n=10)

eBeam (VSB), 28.8%

eBeam (raster), 0.6%

LASER, 70.6%
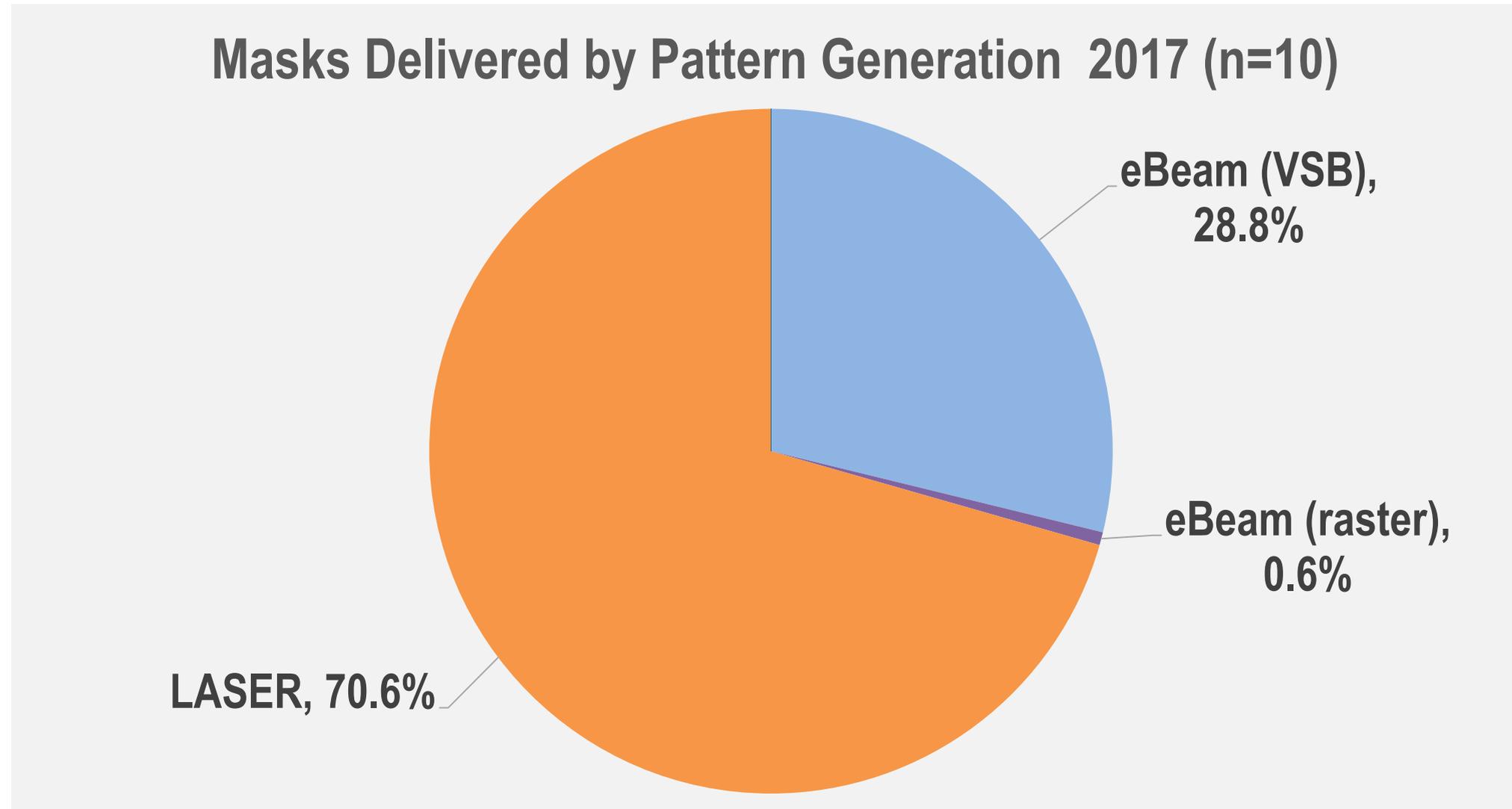
Q: What was the % written by the following pattern generation?
        eBeam (VSB), eBeam (multi-beam), eBeam (raster), LASER, Other

Dry Etch and Wet Etch continue to be 50-50
Leading Edge correlated with Dry Etch

2016 (n=9)

Dry Etch, 49%

Wet Etch, 51%

2017 (n=10)

Dry Etch, 43.6%

Wet Etch, 56.4%
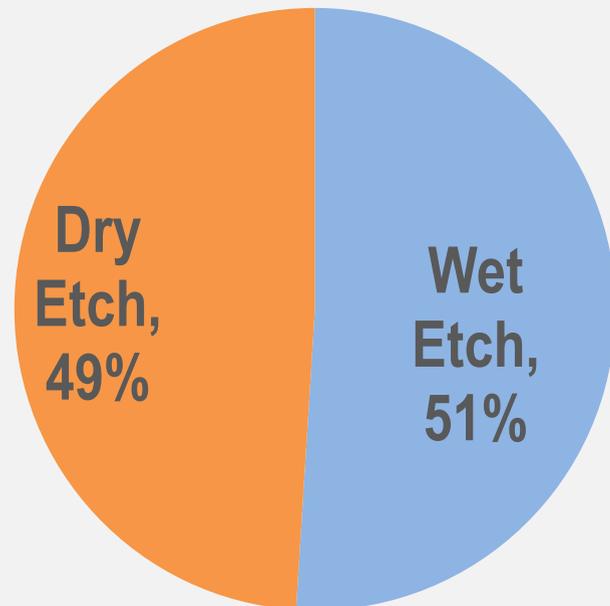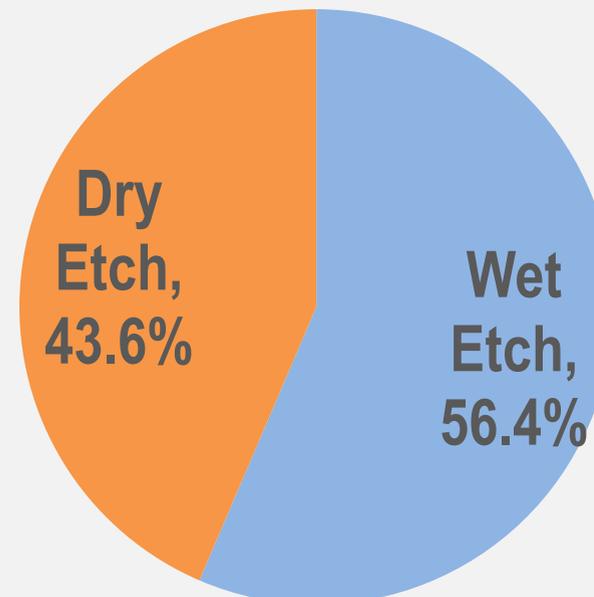
2017 Leading Edge Weighted Avg (n=10)

Dry Etch, 53.59%

Wet Etch, 46.41%
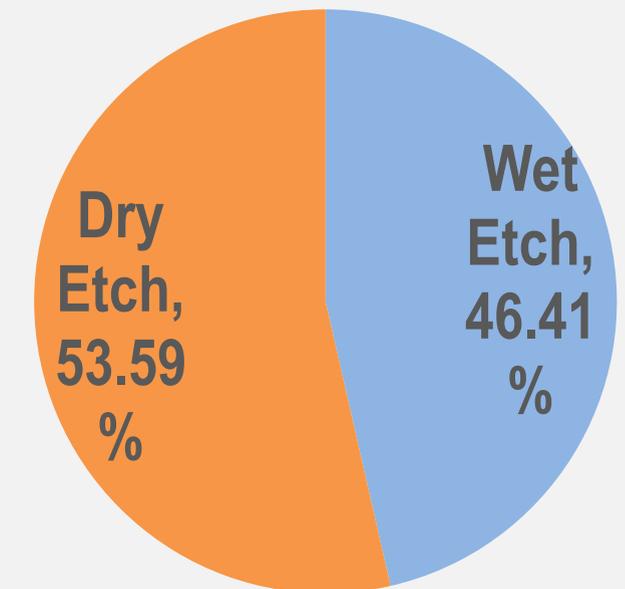
Q: What was the percentage by…?
   Wet Etch, Dry Etch

Leading Edge Weighted Average is computed by averaging each company response multiplied by that company's percentage share of <45nm ground rule masks reported.

Avg Mask Write Times Are Being Contained
Writer Times Separately Reported in 2017

Average Mask Write Times 2015-2017
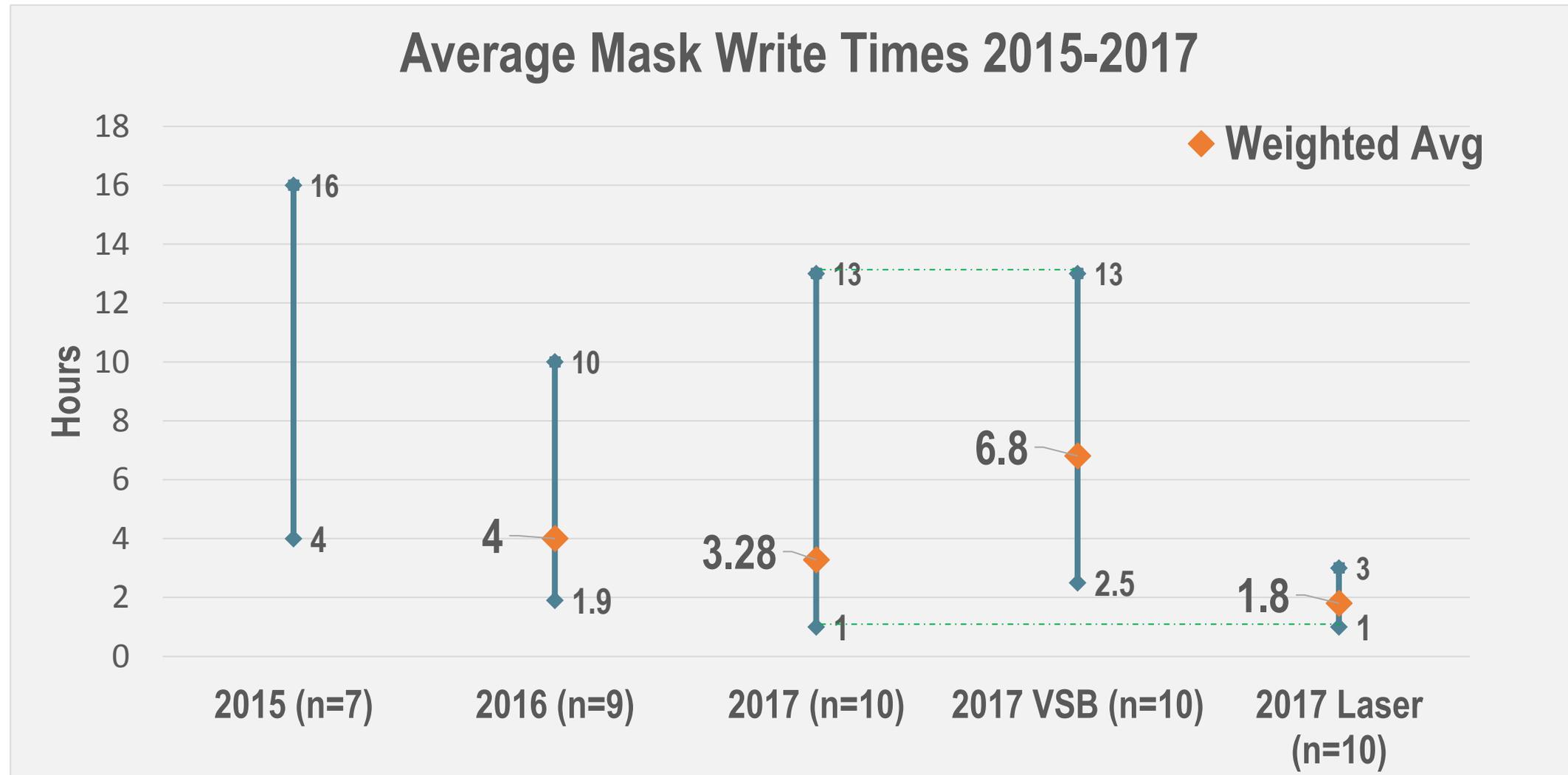
Q: What was the average write time for each type of pattern generation?

Weighted Average is computed by averaging each company response multiplied by that company's percentage share of the reported masks for 2016 and 2017 results. 2015 survey did not include the number of masks by participant. For VSB and Laser, each response of each writer type is weighted by percentage share of that company of total reported masks of that type..

Longest Write Times: 60 Hrs VSB, 18.4 Hrs Laser

Range of Longest Mask Write Times 2015-2017
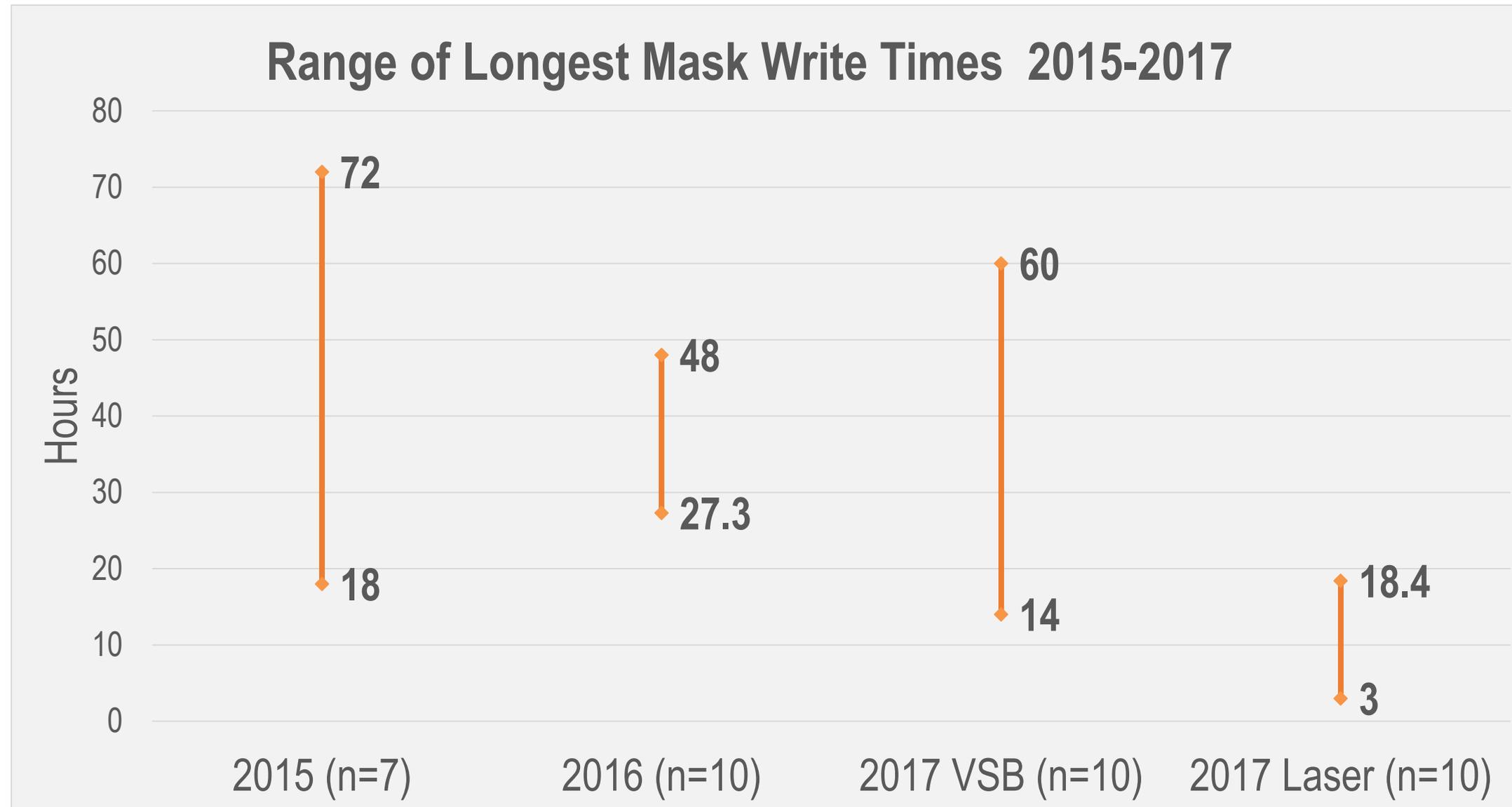
Q: What was the longest write time for each type of pattern generation?

Largest Data Volume Reported in 2017 ~ 2 TB
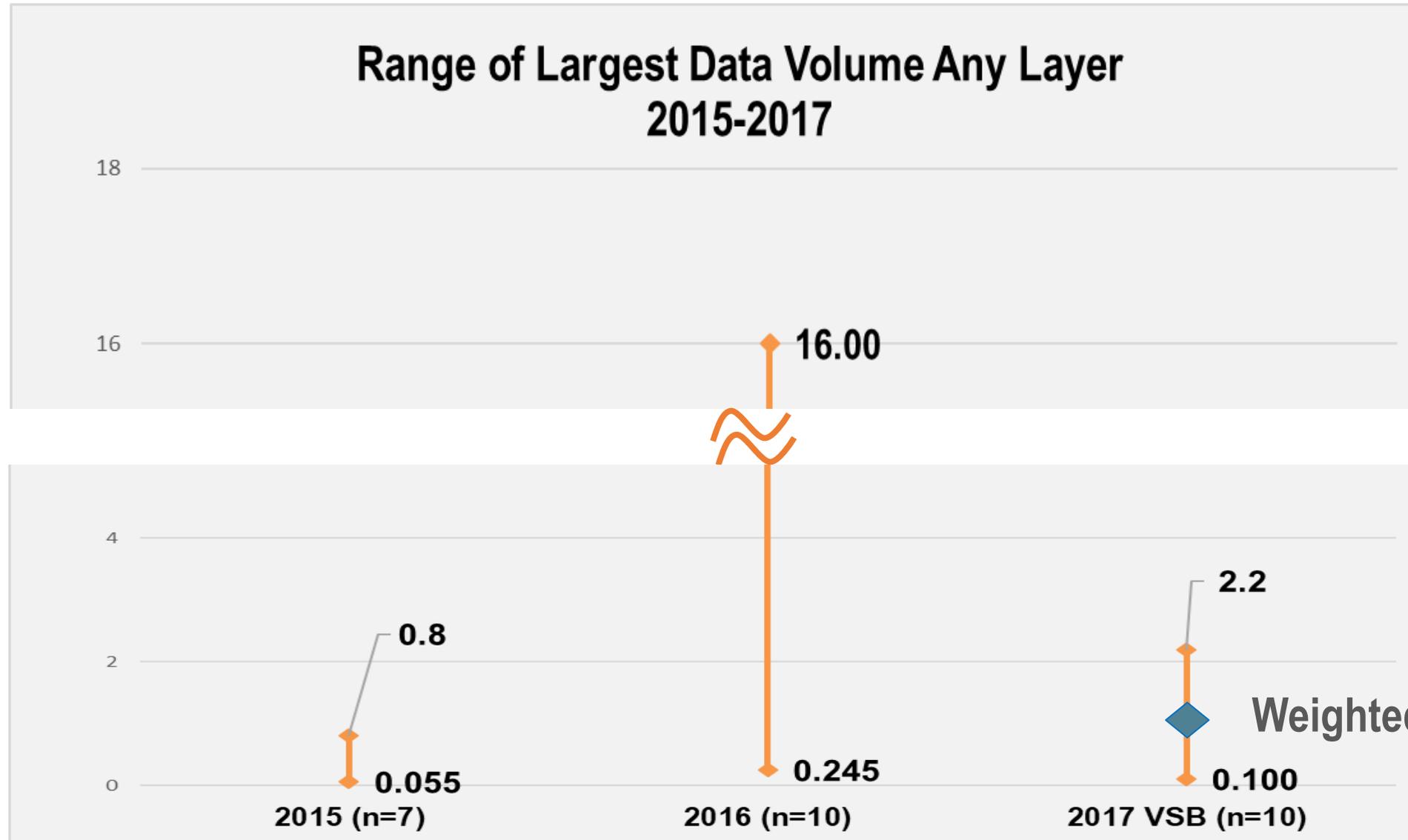
Range for laser was 500KB to 30GB with weighted avg of 8GB

Q: What was the largest data volume for any mask level for each type of pattern generation?

Weighted Average is computed by averaging each company response multiplied by that company's percentage share of all reported masks of the writer type.

As Expected: TAT Worse at Leading Edge
Maximum reported was 21 days

TAT Weighted Avg
2016 (n=9) vs 2017 (n=8)
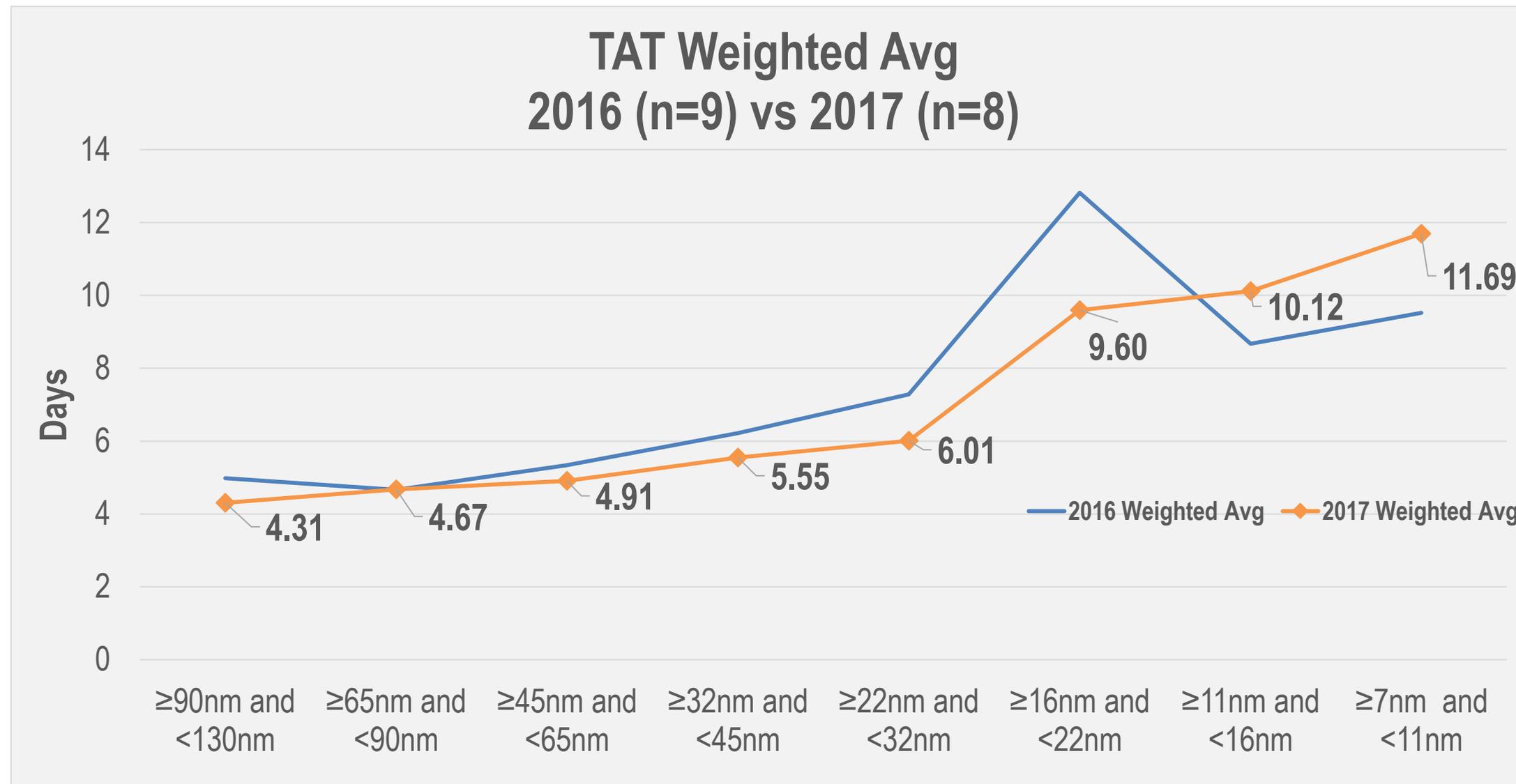
Q: What was your average Turn-Around-Time (TAT) by Ground Rules?

Weighted Average is computed by averaging each company response multiplied by that company's percentage share of all reported masks

112 Masks per Mask Set was the 2017 High

 # Masks Per Mask Set by Ground Rule
2017 Weighted Avg (n=6)
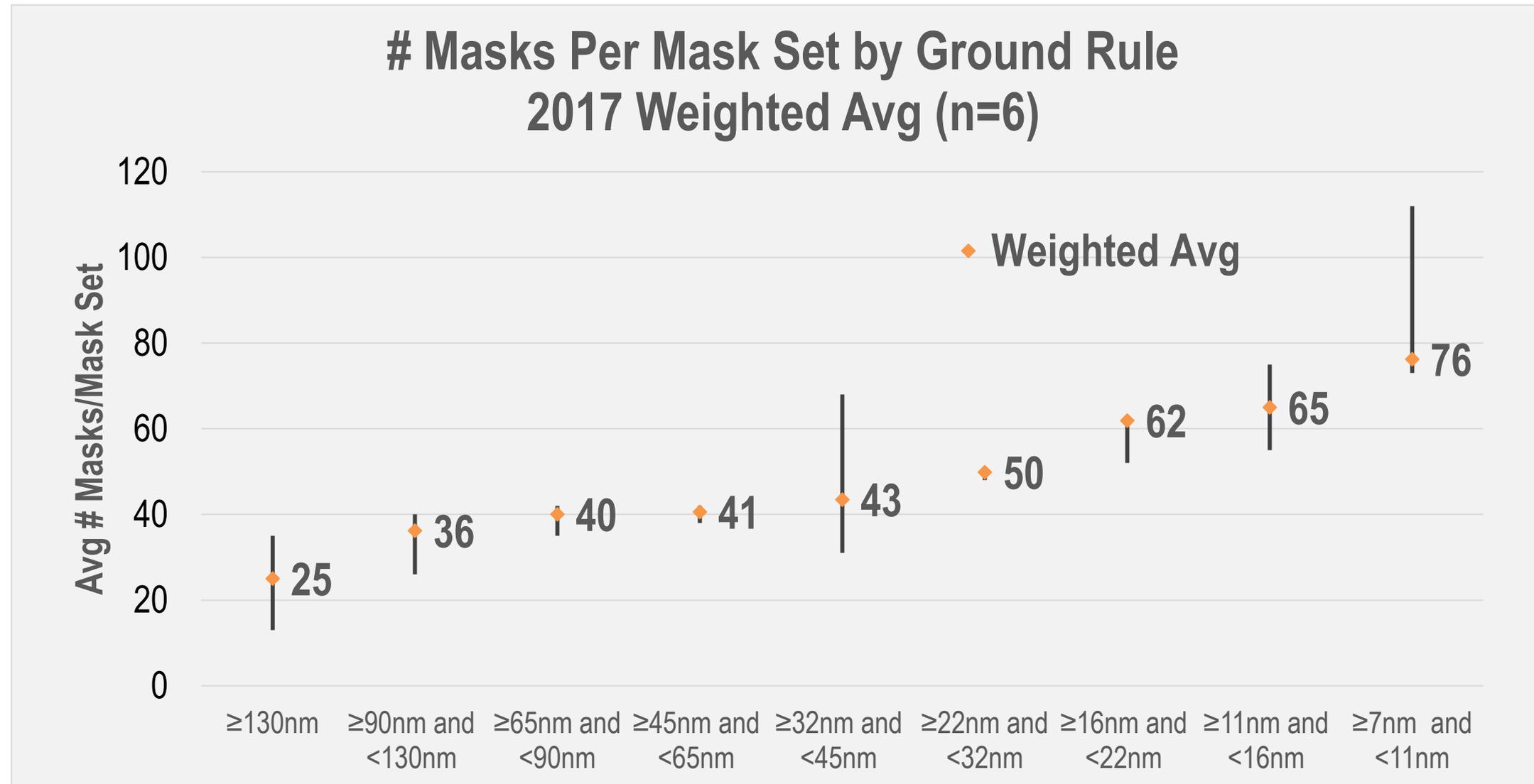
Q: What was the average # of masks per mask set by Ground Rules?

Avg # of Defects Increased

Avg # of Defects per Mask by Type
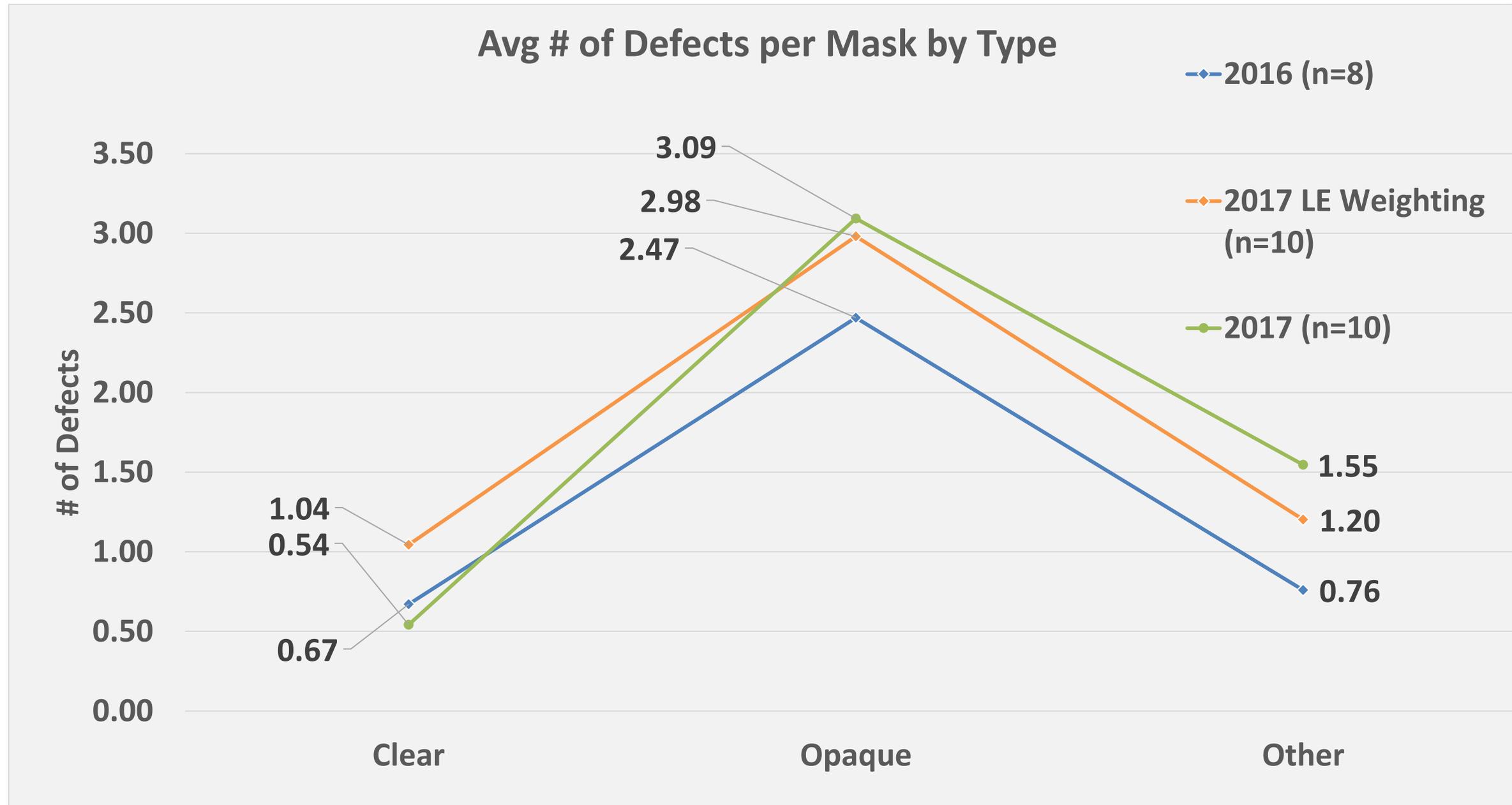
Q: What was the average number of defects per mask?

Leading Edge Weighted Average is computed by averaging each company response
multiplied by that company's percentage share of <45nm ground rule masks reported.

eBeam, Nanomachining Increase at Leading Edge

No Repair

Mask Repair by Type

Legend: 2016 (n=8) · 2017 (n=10) · 2017 LE Weighted Avg
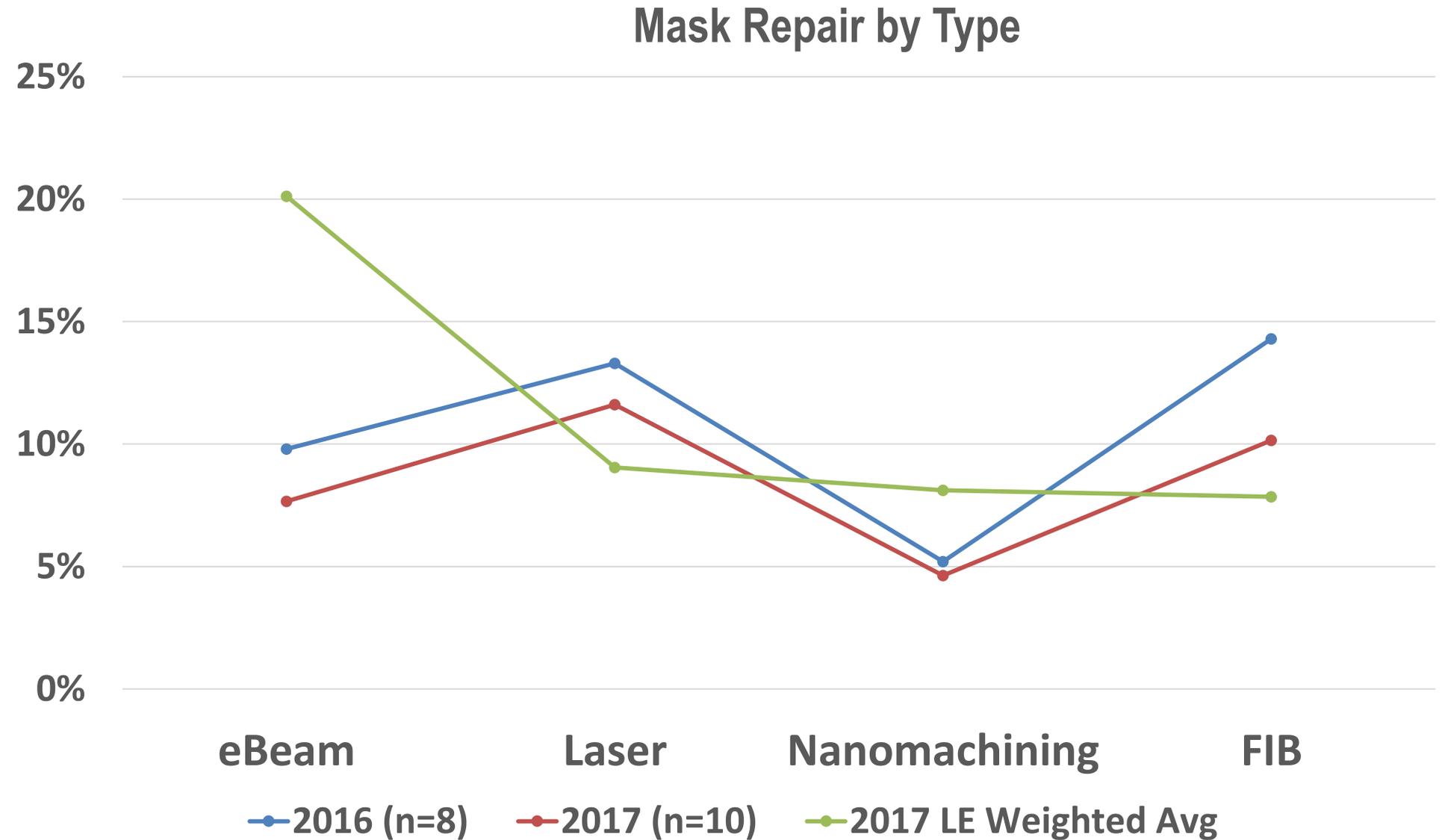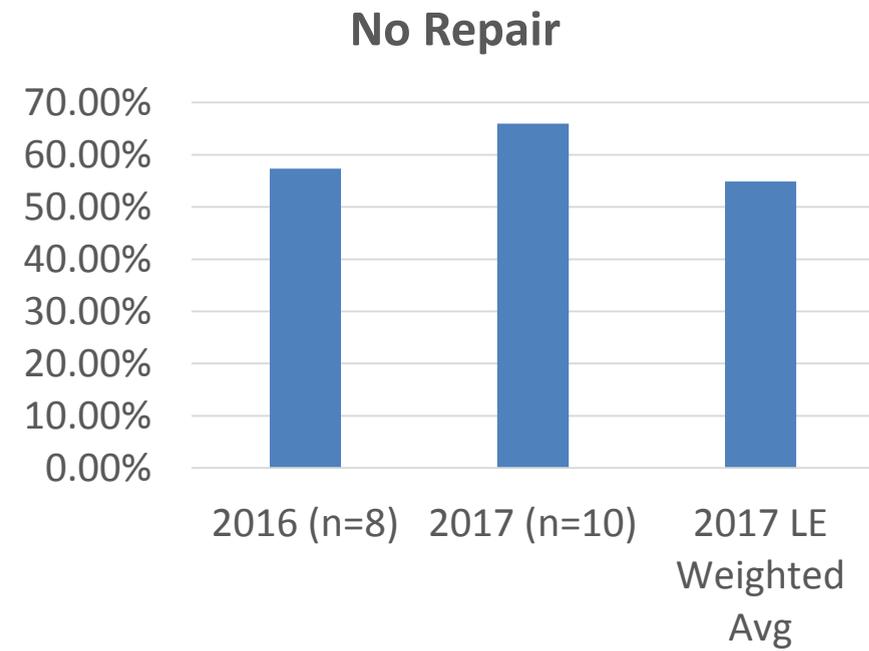
Q: What was the percentage of masks repaired by…?
No Repair, eBeam, LASER, Nanomachining, FIB

Leading Edge Weighted Average is computed by averaging each company response
multiplied by that company's percentage share of <45nm ground rule masks reported.

Data Prep Error is the #1 Cause of Returns
0.31% of Masks are Returned

Breakdown of Causes - 2017 (n=9)

- Soft Defects, 16.6%
- Hard Defects, 8.9%
- Data prep errors, 28.1%
- Bad repair, 1.2%
- Wrong Pellicle/Damage, 3.1%
- Haze, 4.0%
- Other, 38.1%
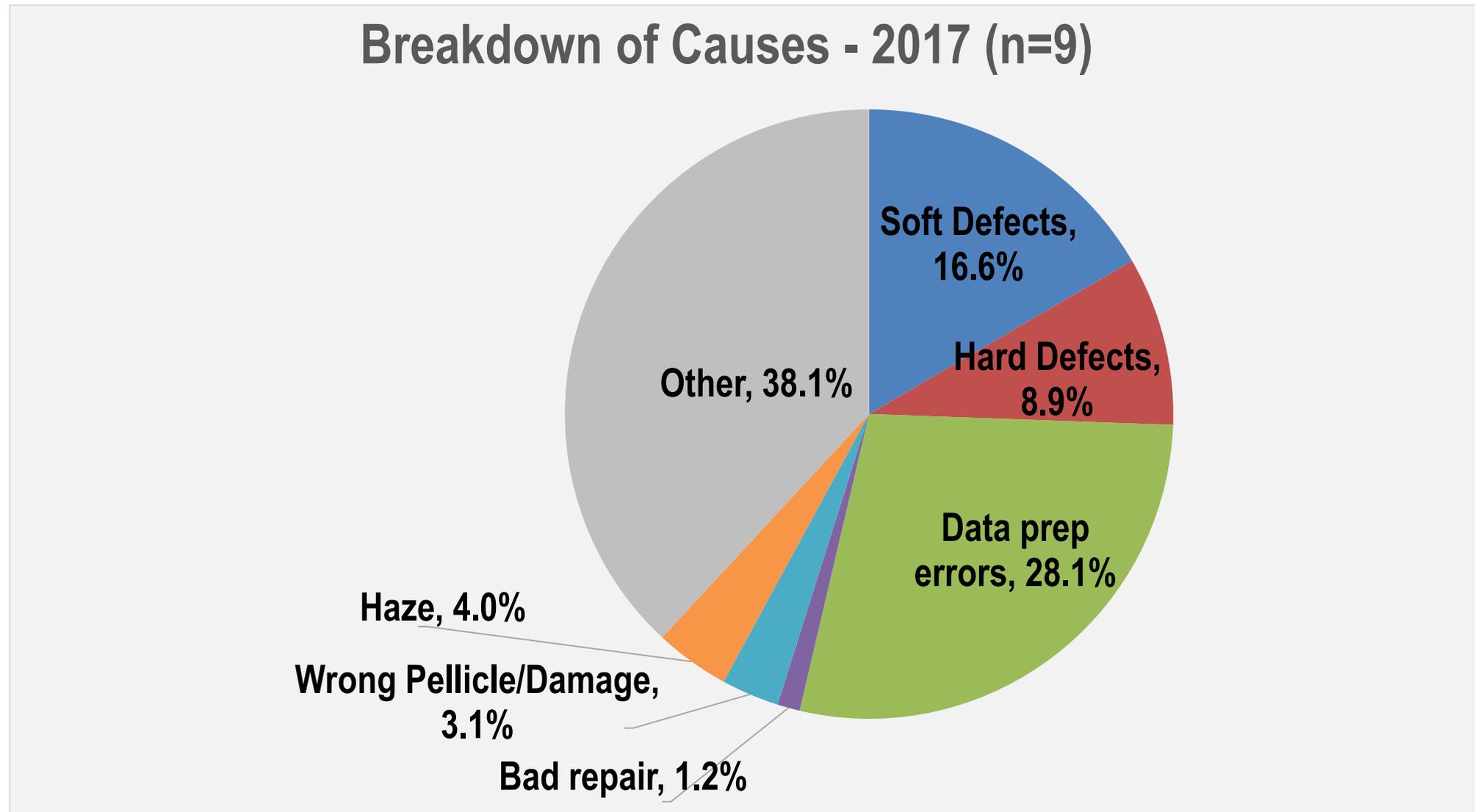
Q: What percentage of masks were returned from the fab?

Q: Of the masks returned from the fab, what percentage were attributed to the following causes?

2017 Mask Yield was 94.8%

Category	Yield
All Masks	94.8%
EUV	64.3%
AltPSM	69.9%
AttPSM	89.7%
Binary	96.1%

n=10
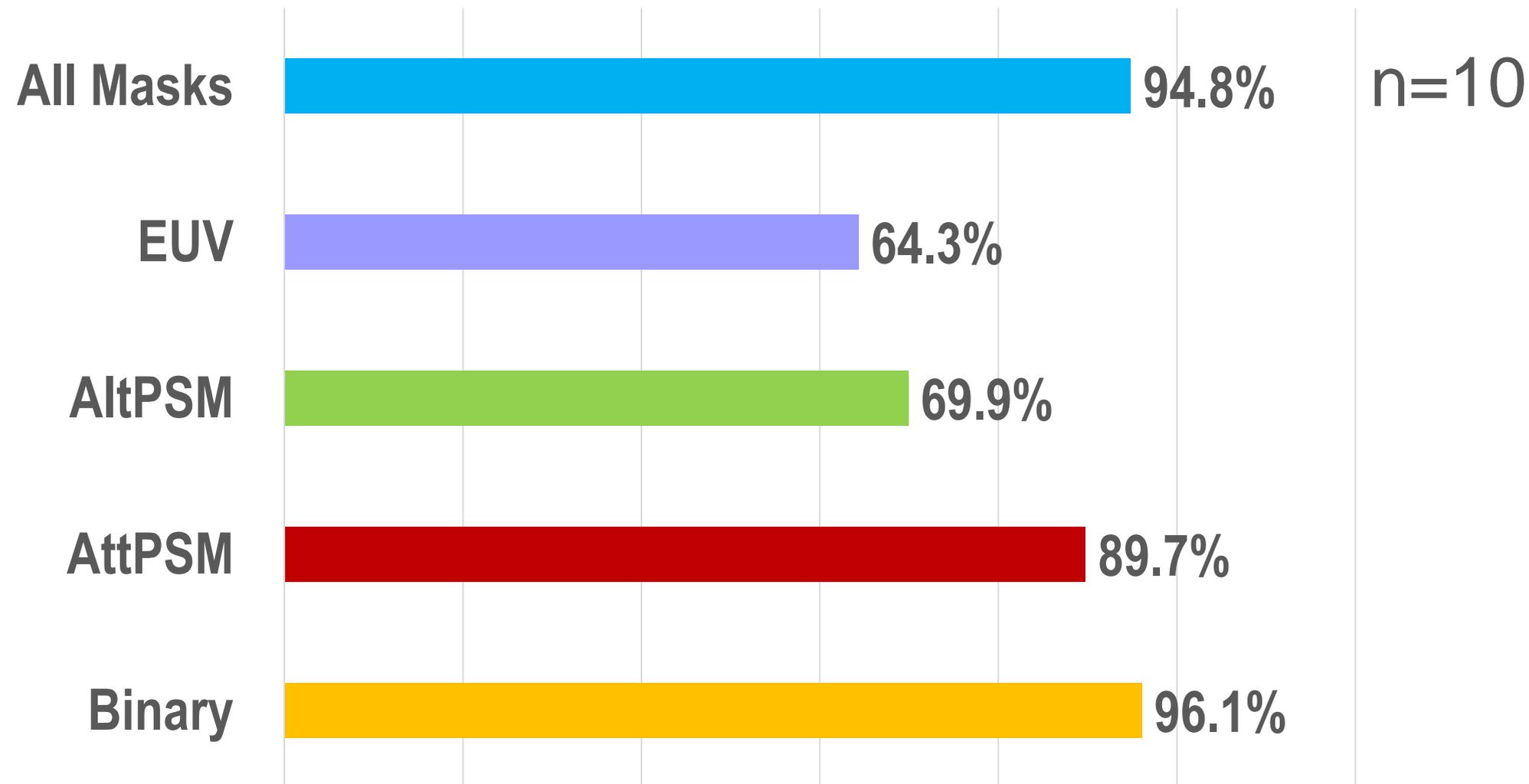
n=9 for yield by category

Q: What was your overall mask yield?
Q: What was your percent mask yield by category?

Weighted Average is computed by averaging each company response of each category multiplied by that company's percentage share of reported masks of that category

Data Prep Time Increases at Leading Edge

Avg Data Prep Time - 2017 (n=8)
(starting point defined as RET output)

- ◆ Weighted Avg (outliers removed)
- ● Weighted Avg

Ground Rule	Weighted Avg (outliers removed)
≥130nm	2.78
≥90nm and <130nm	3.39
≥65nm and <90nm	5.00
≥45nm and <65nm	7.59
≥32nm and <45nm	9.21
≥22nm and <32nm	9.12
≥16nm and <22nm	14.31
≥11nm and <16nm	15.55
≥7nm and <11nm	21.12
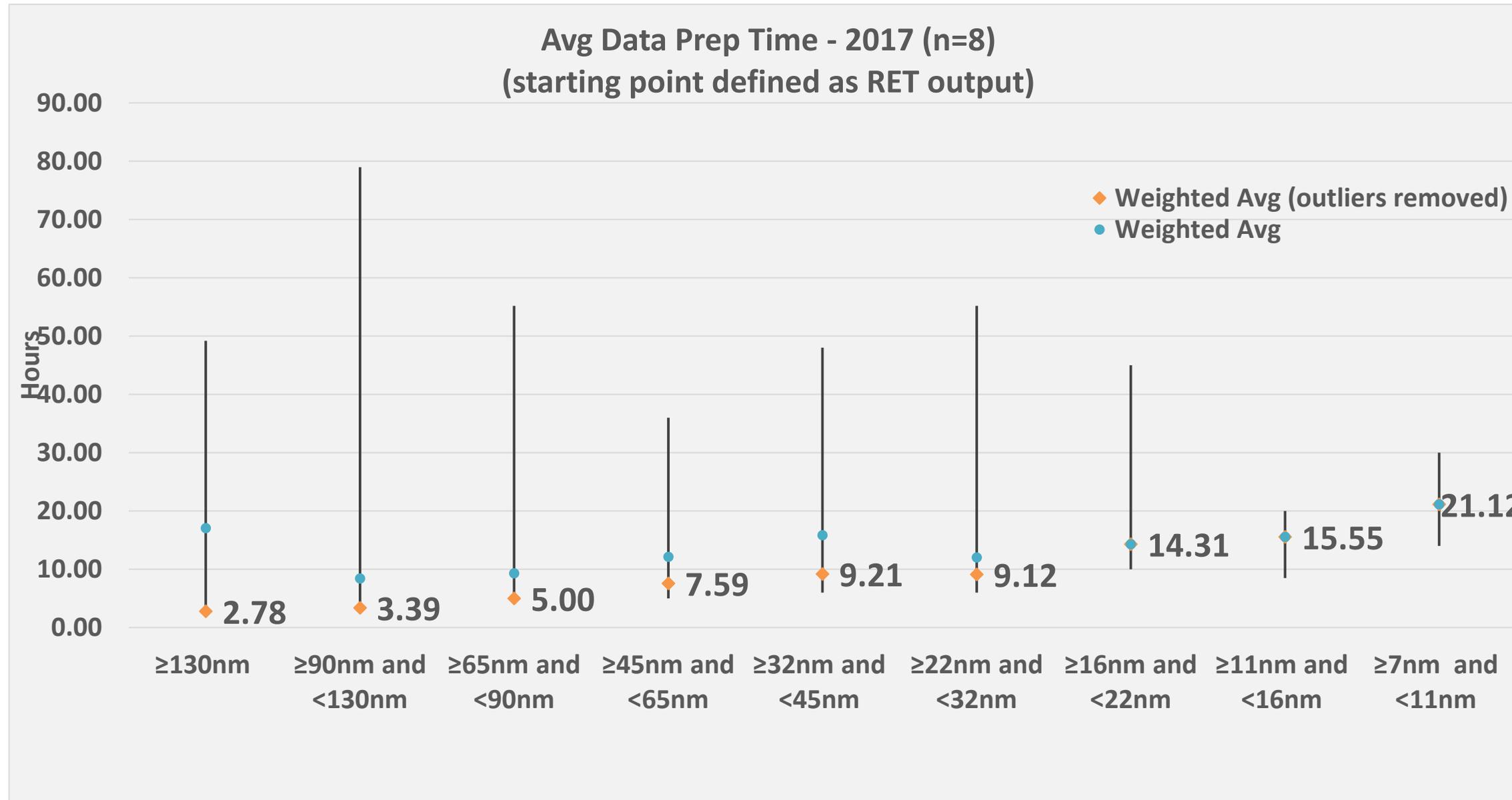
Q: What was the average data prep time (starting point defined as RET output) by Ground Rules?

Weighted Average is computed by averaging each company response of each category multiplied by that company's percentage share of reported masks of that category.

MPC Becomes a Requirement Below 16nm

% Masks with MPC Applied
2017 (n=9)
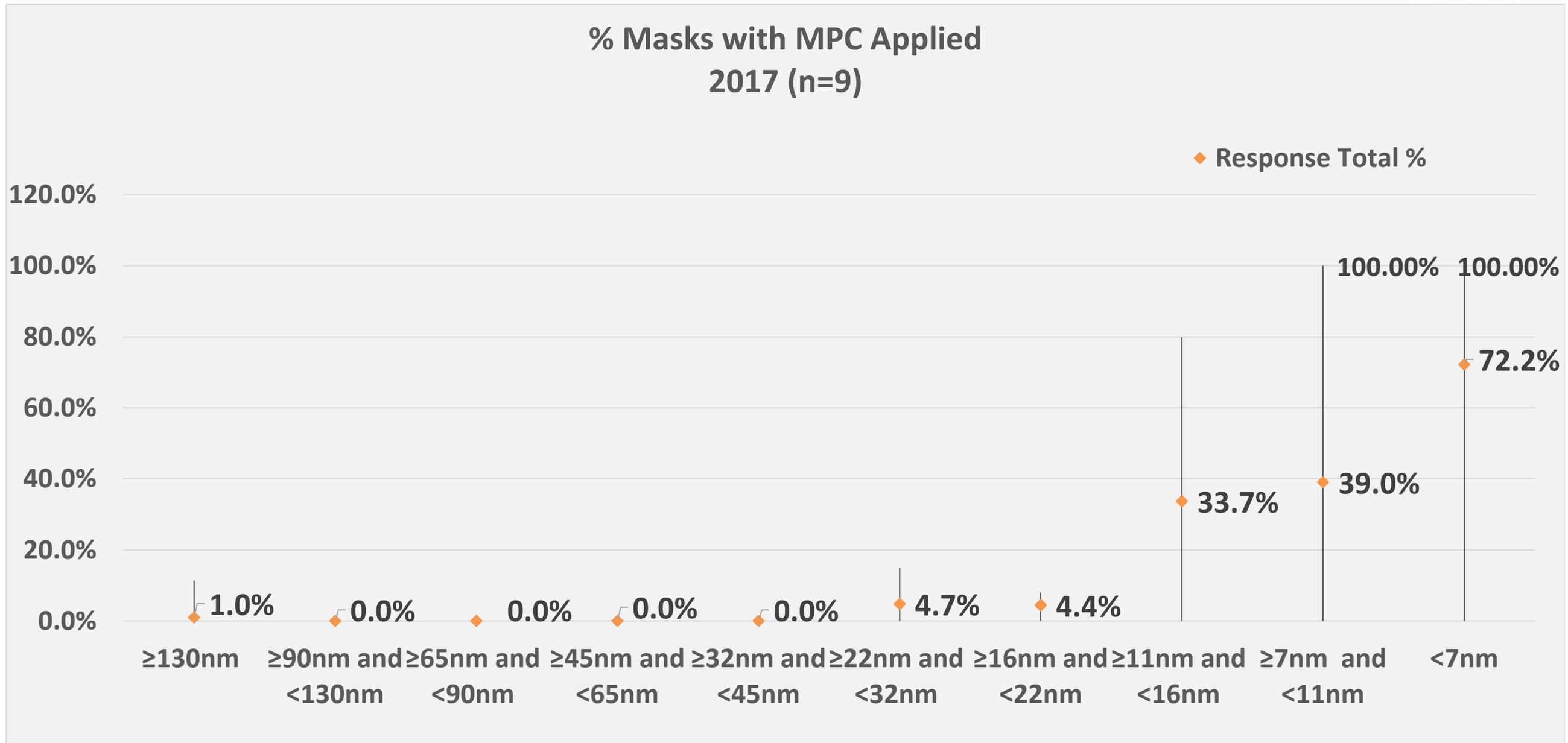
Q: What % of masks by ground rules had Mask Process Correction (MPC) applied?

Strong Participation in 2017 Mask Survey

- 10 mask makers in total – 1041 EUV masks reported vs 382 in 2016

- Mask write times are being contained

  - 60 hours the longest write time reported for eBeam VSB writers

  - 18.4 hours the longest write time for Laser writers

- Data prep is the leading cause of mask returns

- Mask data prep time is increasing at advanced nodes

- Mask process correction (MPC) is becoming a new requirement <16nm