

Report on first ever cleaning of WHT Secondary Mirror (M2) on 23 March 2018 by Emilie Lhomé and Neil O'Mahony,

using Soap & Water, Propanol & Tissues and First Contact polymer. Measurements of Reflectivity & Scattering before and after each from CT7.

Conclusion: multiple cleaning methods improved coating performance by less than 1% in blue, but no effect in other wavebands. Spotting remains. Spotting was the main motivation to try cleaning, but now appears only new Aluminisation can remedy this. Last alum was 04/2009, 9 years ago.

Inspection:

M2 inspection shows a uniform covering of tiny, light-coloured spots and a half dozen dark coloured holes (actual gaps in the coating, 1-2 mm diameter) These spots are probably correspond to the pinholes seen in transmission in older metal coated mirrors (both Al and Ag).

M2 is probably too thick to allow transmission inspection (removing from mirror cell was not discussed). The UV lamp reflection provided no insight in this case Tests on the Coude1 mirror suggest pinholes preferentially reduce blue reflectivity, while clear areas can be almost as good as fresh aluminium.



Fig 1. (above) closeup of stained, scratched area near top edge (radial extent ~5cm). First Contact polymer was applied several times to this area, reducing stain, but scratch damage remained. See also spotting: why some appear elongated is uncertain.

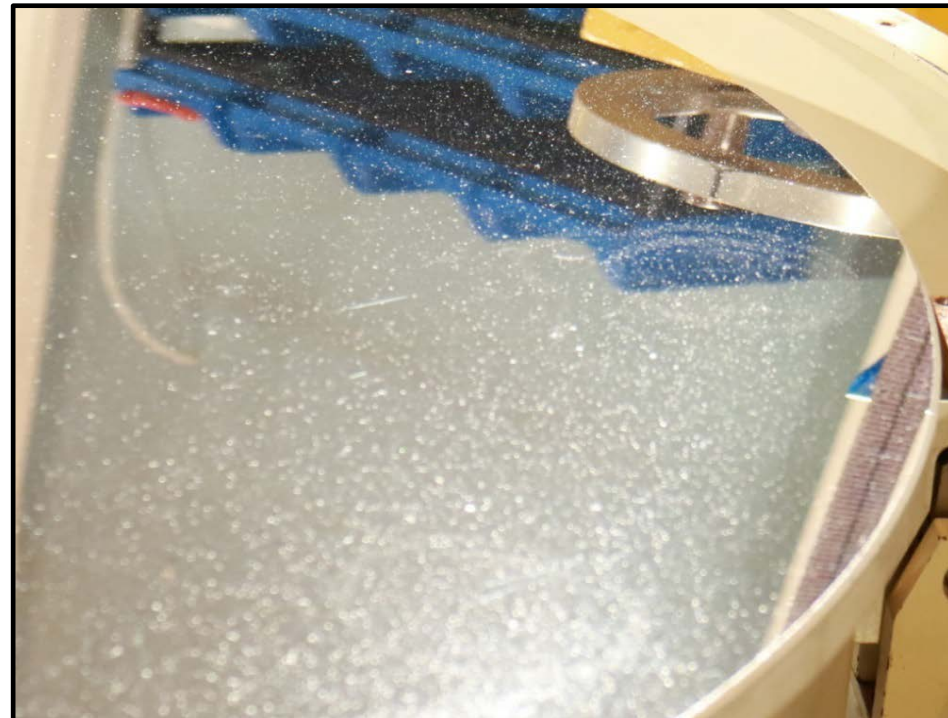


Fig. 2. (above) is a wider angle view of the top half of the mirror showing the uniform distribution of light coloured spots. These spots show up in oblique lighting, while bright area at bottom is close to specular source reflection. Two rings above right -center are marks left by the SMS uScan reflectometer head, last used several years previously.

Procedure:

During washing, M2 was held vertical, tipped slightly forward in its trolley, using the dome crane. The outer annular part of the baffle was removed, to allow the sides of the mirror, cell and actuators to be dried afterwards. Plastic sheeting was attached to mirror lower edge to avoid wetting inside cell. Our usual wash procedure came first: deionised water sprayed on, then Orvis soap solution in warmed deionised water dabbed on with natural sponges. Soap rinsed off by deion. water spray, then blow dry with dry air supply. CT7 measurements taken in vertical position before next cleaning stages. This was application of First Contact and propanol to two well-identified stains near "top" of mirror. New measurements taken after removal of agents. First Contact repeated on same stain due to difficulty removing (dries slowly in cold). Rest of surface given a general propanol wash, dragged by large synthetic tissue, before water rinse and blow dry. Final measurements with mirror at horizontal position, sampling same locations as initially.

Measurements:

Initial measurements on M2, horizontal, before cleaning. Cardinal positions around edge & centre. Green highlight for best values, dark orange for worst.

index	date & time	pos	i.d.	Tempr. °C	wavelength of band (nm)								"Dust Indices"						
					365	404	464	522	624	760	970	365	404	464	522	624	760	970	
1337	23/03/2018 09:53	R	M2	21.8	83.3	83.8	85.0	86.1	85.5	84.1	91.0	18.6	12.6	11.3	7.7	10.5	5.2	5.8	
1338	23/03/2018 09:54	R	M2	21.8	85.0	85.3	86.3	87.6	86.8	85.0	91.8	9.0	7.7	7.4	4.1	5.0	3.0	2.7	
1339	23/03/2018 09:55	top	M2	21.8	86.4	86.4	87.2	88.0	87.7	85.3	92.1	7.0	5.7	5.2	3.1	3.4	2.2	2.0	
1340	23/03/2018 09:56	top	M2	21.8	84.8	84.8	86.2	86.8	86.8	84.7	91.0	10.3	8.9	8.9	5.6	5.7	3.6	4	
1341	23/03/2018 09:56	L	M2	21.6	85.5	86.2	86.7	88.0	87.4	84.9	91.8	9.6	7.2	8.0	3.7	5.1	3.8	2.8	
1342	23/03/2018 09:57	L	M2	21.6	84.1	83.7	85.3	86.0	85.7	84.0	90.8	11.7	11.3	9.8	7.5	8.0	4.9	4.5	
1343	23/03/2018 09:58	lwr	M2	21.4	85.0	84.7	85.7	86.9	86.1	84.6	91.2	11.3	9.6	8.2	4.4	5.7	3.4	2.5	
1344	23/03/2018 09:59	lwr	M2	21.4	84.1	84.2	85.1	86.2	86.2	83.9	90.9	18.4	19.6	10.6	9.6	7.8	5.4	5.8	
1345	23/03/2018 10:00	lwr	M2	21.3	84.1	84.2	85.4	86.5	86.5	84.2	91.2	10.6	10.5	8.9	6.0	5.8	3.8	3.7	
1346	23/03/2018 10:01	ctr	M2	21	84.9	85.3	86.5	87.4	87.5	84.9	91.9	8.9	7.6	6.5	4.1	3.8	2.6	2.1	
1347	23/03/2018 10:02	ctr	M2	20.9	84.2	84.3	85.8	86.0	86.9	84.4	91.5	10.9	10.3	9.2	7.0	5.3	4.5	3.4	
1348	23/03/2018 10:03	ctr	M2	20.8	84.8	85.2	86.5	87.3	87.3	84.9	91.8	9.4	7.7	6.3	4.2	3.8	2.5	2.3	
1349	23/03/2018 10:04	ctr	M2	20.7	84.6	85.1	86.3	87.2	87.3	84.4	91.8	10.5	8.6	7.4	4.8	4.3	3.2	2.7	
Averages (omit 1344*, 1337)					84.7	84.9	86.1	87.0	86.8	84.6	91.5	9.9	8.6	7.8	5.0	5.1	3.4	3.0	
Best value					86.4	86.4	87.2	88.0	87.7	85.3	92.1	7.0	5.7	5.2	3.1	3.4	2.2	2.0	
Worst Value					83.3	83.7	85.0	86.0	85.5	83.9	90.8								
range (best-worst)					3.1	2.7	2.2	2.0	2.2	1.4	1.3								

*1345 was a repeat measurement near the position of the previous measurement

Comparison with previous data:

Average of 3 meas. from 3/2017	83.9	84.4	85.5	87.1	87.0	84.7	91.7	11.7	10.0	9.9	4.7	5.8	3.3	2.7
Difference now from 2017	0.8	0.6	0.6	-0.1	-0.2	-0.1	-0.2	1.7	1.4	2.1	-0.2	0.7	-0.1	-0.3

Note 1: reference measurements imply reflectivity overestimated ~0.4% in the first and last wavebands. (See Note on Calibration at end).

This would reduce the apparent increase in %R at 365 nm to ~0.4%, marginally significant. However, scattering increase appears real and makes sense.

Note 2: 2017 sample affected by 1 low reading but still within range of current sample. We cannot say %R has degraded further since 2017, but Scattering has.

After Soap & Water wash, measured with mirror vertical: requires holding CT7 steady. Yellow highlight on value lower than any seen before wash.

				365	404	464	522	624	760	970	365	404	464	522	624	760	970
1350	23/03/2018 10:49	7 M2	18.8	85.5	85.1	85.9	87.2	86.6	84.2	91.7	11.2	10.8	10.5	6.4	7.7	5.9	4.0
1351	23/03/2018 10:50	7 M2	18.9	83.3	83.6	85.6	85.3	86.3	84.2	90.5	14.8	13.0	10.3	8.2	7.1	4.9	5.1
1352	23/03/2018 10:51	7 M2	19.0	84.6	85.0	86.5	87.2	87.3	85.0	91.9	10.1	8.6	7.1	4.6	4.4	2.9	2.6
1353	23/03/2018 10:54	7 M2	19.2	85.4	85.2	85.9	87.0	86.7	84.3	91.2	12.2	12.7	10.2	7.6	8.7	5.3	5.0
averages				84.7	84.7	86.0	86.7	86.7	84.4	91.3	12.1	11.3	9.5	6.7	7.0	4.8	4.2
average, omitting bad value (highlight)				85.2	85.1	86.1	87.1	86.9	84.5	91.6	11.2	10.7	9.3	6.2	6.9	4.7	3.9
change in average from before wash				0.4	0.2	0.0	0.1	0.1	-0.1	0.1	1.2	2.1	1.5	1.2	1.9	1.3	0.9

Surprisingly, all scattering measurements are again larger than the average from before washing. May be a sampling issue, but no notes to confirm this.

Measurement after removal of **First Contact polymer** from small area near top edge, scratched and with apparent stains (see photo in Fig 1.)

1354	23/03/2018 11:08	7 M2	16.8	86.0	86.1	86.8	87.9	87.0	85.3	92.0	9.9	8.8	8.5	4.8	6.6	3.7	3.2
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Measured on small **alcohol-cleaned area** having a cluster of tiny spots, top left. Natural drying. These spots could not be removed.

1355	23/03/2018 11:10	7 M2	16.4	86.9	86.7	87.4	87.8	87.9	84.5	92.1	9.4	8	7.4	5.2	4.8	5	2.9
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After first **Alcohol drag cleaning** of left hand side (deionised water rinse while still wet, blown dry).

1356	23/03/2018 11:15	7 M2	16.1	85.3	86	87.2	87.6	87.7	85.3	91.8	9.3	7.4	6.2	4.6	4.3	2.9	2.8
1357	23/03/2018 11:16	7 M2	16.1	84.8	84.5	85.7	86.4	86.7	83.9	91	7.6	7.8	7.2	4.9	4.7	4.7	2.9
1358	23/03/2018 11:24	7 M2	15.5	86.7	86.7	87.3	88.1	87.9	85.4	92.1	8.8	8	7.5	4.7	4.6	3.5	2.7

averages of both test areas				85.9	86.0	86.9	87.6	87.4	84.9	91.8	9.0	8.0	7.4	4.8	5.0	4.0	2.9
Difference of averages wrt Soap+Water				0.8	0.9	0.8	0.4	0.6	0.4	0.2	-2.2	-2.7	-1.9	-1.4	-1.9	-0.7	-1.0

These averages are significantly better than the sample of 4 taken straight after water washing, justifying completion of alcohol drag wash on right half of mirror.

Note blue highlight above correspond to the overall highest reflectivity measured after all cleaning.

Final measurements, mirror horizontal, sampling same locations as initially. Yellow highlight for a value worse than any before cleaning (omit).

			365	404	464	522	624	760	970	365	404	464	522	624	760	970	
1359	23/03/2018 11:53	rt M2	12.5	86.6	86.5	87.2	87.6	87.9	84.8	92.1	7.3	6.5	5.9	4.5	3.4	3.4	2.2
1360	23/03/2018 11:54	rt M2	12.7	84.1	84.4	84.2	86.7	85.4	84.3	91.3	15.1	12.3	14.6	6.7	10.2	4.6	3.6
1361	23/03/2018 11:55	top M2	12.9	86.6	86.4	87.1	87.8	87.7	85.1	92.0	8.0	7.5	6.9	4.8	4.5	3.3	2.5
1362	23/03/2018 11:56	top M2	13.2	86.7	86.4	86.7	87.7	87.2	84.4	91.9	7.5	7.2	9.1	4.1	6.4	5.0	2.2
1363	23/03/2018 11:57	L M2	13.4	86.3	85.8	86.0	87.4	86.9	84.6	91.5	8.6	9.5	9.3	4.9	6.2	4.1	3
1364	23/03/2018 11:58	L M2	13.6	85.2	85.5	86.3	87.1	86.3	84.5	91.3	10.9	8.4	8.0	4.9	7.3	3.8	3.1
1365	23/03/2018 11:58	lwr M2	13.8	85.3	84.8	86.0	86.4	86.8	84.4	91.0	9.8	9.4	8.3	5.9	5.2	3.8	3.3
1366	23/03/2018 11:59	lwr M2	14.0	82.5	82.9	83.7	85.5	85.4	82.7	89.9	17.8	16.1	16.9	8.7	10.5	8.5	6.7
1367	23/03/2018 12:02	ctr M2	14.3	84.7	85.2	86.3	87.2	87.3	84.8	91.7	9.8	8.5	7.4	4.9	4.5	3.1	2.7
1368	23/03/2018 12:03	ctr M2	14.4	84.8	84.9	86.2	87.2	87.4	84.8	91.7	9.4	8.4	7.1	4.7	4.2	2.8	2.4
Final Averages (omit 1366)				85.6	85.5	86.2	87.2	87.0	84.6	91.6	8.9	8.2	7.8	4.8	5.2	3.7	2.7
range (omitting 1366)				4.2	3.6	3.5	2.3	2.5	2.4	2.2							
Standard error on the mean				0.3	0.3	0.3	0.2	0.3	0.1	0.1	0.8	0.6	0.8	0.3	0.7	0.2	0.2
Difference from Soap&water averages				0.4	0.4	0.1	0.1	0.1	0.1	0.0	-2.3	-2.5	-1.5	-1.4	-1.7	-1.0	-1.2
Difference fr. Prev. alcohol wash (vertical)				-0.4	-0.5	-0.7	-0.3	-0.5	-0.2	-0.2	-0.1	0.2	0.4	0.0	0.2	-0.3	-0.2
Difference from before-wash avg.				0.9	0.6	0.1	0.3	0.2	0.0	0.1	-1.0	-0.5	-0.1	-0.1	0.1	0.3	-0.3

Measurements after **final removal of First Contact film**, applied 3 times to stained area (Fig 1.) Stains much reduced, but not scratches.

1369	23/03/2018 13:35	7 M2	8.9	83.6	82.9	84.2	85.7	85.4	83.4	90.8	12.5	13.9	13.5	8.6	9.2	7.3	5.2
1370	23/03/2018 13:36	7 M2	9.1	85.4	85.8	87.0	87.7	87.0	85.2	91.7	8.9	7.3	5.9	4.1	5.0	2.7	2.8
1371	23/03/2018 13:37	7 M2	9.4	86.7	86.4	87.0	87.8	87.7	84.9	91.9	6.8	6.7	6.3	4.3	4.0	3.3	2.4
Best value measured M2 horizontal				86.7	86.5	87.2	87.8	87.9	85.1	92.1	6.8	6.5	5.9	4.1	3.4	2.7	2.2
Best overall, from all cleaning techniques				86.9	86.7	87.4	88.1	87.9	85.4	92.1	6.8	6.5	5.9	4.1	3.4	2.7	2.2
Difference in best values w.r.t. pre-clean				0.5	0.3	0.2	0.1	0.2	0.1	0.0	0.2	-0.8	-0.7	-1.0	0.0	-0.5	-0.2

Green highlight is on the best or joint-best value in this session of measurements, with mirror horizontal. Orange for the worst (pink also omitted from stats).

In the above comparisons of the "Final Averages", the final results show little difference in reflectivity from the 1350-53 sample for Soap & Water but does show significant improvement in scattering. The 1350-53 sample is small and may be biased, but a similar change happens with First Contact. Normally, scattering improves roughly inversely proportionally with reflectivity, but there is no significant improvement in %R after the alcohol wash. Simply put, it appears soap and water improved reflectivity while worsening scattering, which was later improved by the propanol, leaving reflectivity pretty unchanged. First Contact helped both.

Comparison with results from Water Wash of other mirrors

								Scatter (DI%)						
WHT M1 averages 08/2015	90.3	89.0	89.0	89.4	88.7	86.2	92.2	6.6	6.0	5.6	3.9	3.8	2.7	2.3
Difference of averages in M2 w.r.t. INTM1	-4.7	-3.4	-2.8	-2.1	-1.7	-1.6	-0.5	2.4	2.2	2.1	0.9	1.4	0.9	0.4
Difference betw. Best values, M2 w.r.t M1	-2.7	-2.9	-2.2	-1.5	-1.7	-4.2	2.5							
INT M1 averages, 03/2017	89.8	88.8	89.0	89.4	88.8	86.3	92.7	5.0	4.5	3.9	2.7	2.6	1.9	1.8
Difference of averages in M2 w.r.t. INTM1	-4.2	-3.3	-2.8	-2.1	-1.8	-1.7	-1.1	3.9	3.7	3.8	2.2	2.6	1.8	0.9
	365	404	464	522	624	760	970	365	404	464	522	624	760	970

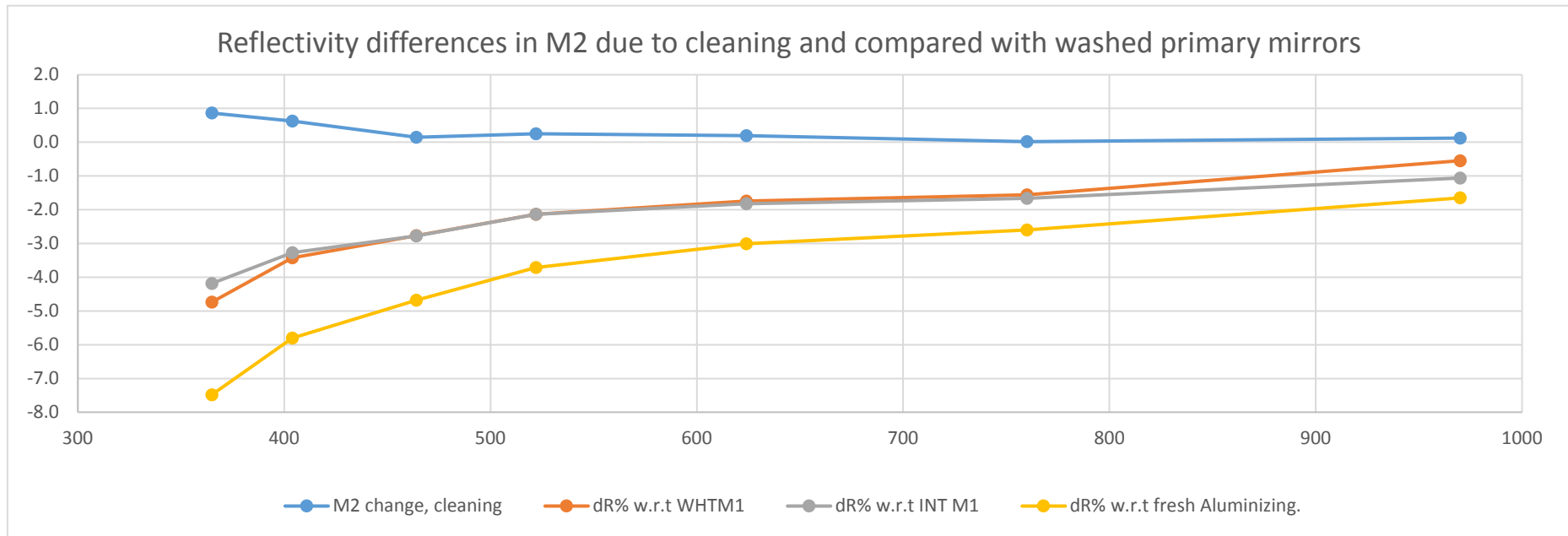
Note the differences in %R for both primary mirrors are **very similar** in each waveband, but the scattering in INT M1 is higher.

Comparison with fresh aluminium

Aluminization (WHT, 2016)	93.1	91.3	90.9	90.9	90.0	87.2	93.3	2.3	2.1	2.0	1.4	1.4	1.1	1.0
Difference w.r.t. Alum., M2 before cleaning	-8.3	-6.4	-4.8	-4.0	-3.2	-2.6	-1.8	7.6	6.6	5.8	3.5	3.6	2.3	2.0
Difference w.r.t. Alum., M2 after cleaning	-7.5	-5.8	-4.7	-3.7	-3.0	-2.6	-1.7	6.6	6.1	5.7	3.4	3.8	2.6	1.7
	365	404	464	522	624	760	970	365	404	464	522	624	760	970

Calibration: since the M2 measurement in 03/2017, the Reference surface ("Gauge") measurement has increased by 0.4% in the 2 extreme wavebands.

Ref changes since 03/2017	0.4	0.1	0.1	0.1	0.1	0.2	0.4	-0.3	-0.4	-0.1	-0.1	-0.2	-0.1	-0.1
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Conclusions:

There is significant evidence of improved average %R and scattering, by ~1% in 365 nm band, ~0.5% in 404 nm, but no change in longer wavelengths.

The Secondary mirror has lower Reflectivity than either of the primary mirrors following their washing, by a minimum ~1% in 970nm, increasing towards blue.

This trend towards blue has been observed several times in CT7 measurements on both aluminium and silver coatings.

It also shows higher scattering than the primary mirrors, despite both the extra cleaning given and the supposedly more favourable downward-facing orientation.

Widespread spotting of the surface, something not observed in washed primary mirrors, remains unchanged by washing.

This strongly suggests the idea that spotting is due to ageing, but lack of earlier cleaning may also influence, by removing corrosive contamination, for example.

Checks on Reference mirror show unchanged readings w.r.t. 2016, but that in 03/2017 in %R, they may have been high in the 2 extreme bands, by up to 0.4%.

These checks confirm that changes in %R and DI show a consistent and smooth increase from a minimum in red wavebands to maximum towards the blue.

In summary, both %R and DI degraded by up to 2% between 2015 to 2016 but in the following year the only perceptible degradation was ~1.5% in Scattering.

This cleaning thus recovered about half of the degradation measurable since 2015 in both Reflectivity and Scattering.

Small sample data suggest that on areas with only alcohol or FC polymer, better results were obtained, particularly in scattering, than in water rinsed areas.

This would require confirmation from a test with a larger sample. Generally we find that large samples (>4) are required, to reduce uncertainty in averages and especially to provide clear results in comparisons. Doing some measurements in vertical orientation has also left them open to doubt.

These results provide suggestions that may improve our cleaning techniques.

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