LEVEL CONTROLS

Selection Guide

Capacitance Calculations and Data
For Selecting
Robertshaw Level Control Instruments
and Sensing Probes

Capacitance Probe Calculations

The following data is compiled to assist you in capacitance applications for selection of the proper instrument and sensing probe. In order to ensure proper use of this data, some definitions are needed.

a. **ZERO** (Level-Tek or Level-Lance, On-Off) - This is the "setpoint" - the point where the desired actuation is to occur.

b. **DIFFERENTIAL** (Level-Tek or Level-Lance, On-Off) - This is the distance, in pico-farads or inches or feet, from ZERO to where "reset" is to occur. Sometimes referred to as "Pump ON to Pump OFF."

CAUTION:
All instruments do not have 100% differential, i.e. 314B has only a 50% differential adjustment. Ensure differential required is within the capabilities of the instrument selected.

c. **ZERO** (Level-Tel or Level-Lance, Continuous) - The 0% level point on the sensing probe.

d. **100%** (Level-Tel or Level-Lance, Continuous) - The FULL level point on the sensing probe.

e. **SPAN** (Level-Tel or Level-Lance , Continuous) - The distance IN PICO-FARADS from the ZERO level point to the FULL level point (100%).

f. **TERMINAL CAPACITANCE -** The MINIMUM amount of capacitance present when NO product is present in the vessel.
This is:
1) The capacitance of the probe gland (and sheath and cooling extension, if used) PLUS
2) The capacitance of the coaxial or triaxial cable when remote mounting an instrument (not applicable for the model 158A or 310) PLUS
3) The capacitance generated between the probe and the vessel with AIR as the dielectric. IN OTHER WORDS, the absolute minimum value of capacitance generated in that particular probe/vessel installation.

NOTE:
Sheath capacitance is same pF/ft. as gain of probe. Cooling extensions are 4 pF for each 4" of extension. Standard coaxial cable capacitance is 12.5 pF/ft. Low noise coaxial cable is 21.5 pF/ft. Triaxial cable capacitance is 17 pF/ft.

g. **TERMINAL/SPAN RATIO -** The "terminal" capacitance divided by the "span" capacitance. This ratio must not be exceeded **where specified** on product specification sheets (all instruments do not have this restriction).

h. **TERMINAL ADJUSTMENT/ZERO ADJUSTMENT RANGE/MAXIMUM ZERO SUPPRESSION -** This is the maximum "zero suppression" of the capacitance value at the zero point level in the vessel. This value cannot be exceeded.

i. **CAPACITANCE CHANGE -** The amount of capacitance difference between ZERO and 100% points in Level-Tel or continuous Level-Lance systems; the amount of capacitance difference between product and no product in point level (Level-Tek/Level-Lance with no Differential) applications; or the amount of capacitance difference between ZERO & DIFFERENTIAL points in Level-Tek/Level-Lance applications utilizing Differential.

j. **TOTAL CAPACITANCE -** The total capacitance value (not capacitance change) with tank or vessel at the 100% level (includes terminal capacitance).

NOTE:
The pF/ft. Minimum and Maximum span of the instrument selected must be met. Ensure Enough Capacitance Change Is Generated To Meet The Minimum Span Requirements And Do Not Exceed The Maximum Span Of The Instrument.

A. INSULATED PROBES

The attached graphs illustrate capacitance in "pico-farads per foot" (pF/ft.), in various vessel diameters, generated by "standard" probes offered by Robertshaw. In the graphs shown, the sensing probe is calculated as being mounted in the center of a cylindrical vessel of the diameter shown. The diameters shown in these graphs are: 4", 14", and 60". The probe capacitance values can be approximated for other vessel diameters by interpolation from the values obtained from these graphs/diameters.

To calculate pico-farad values for any product level, the following facts must be known:

1) Vessel Diameter

2) Product Dielectric value

3) Probe Type and Length

4) Desired ZERO & 100% points, or, the ZERO & DIFFERENTIAL points.

The procedure for utilizing the attached graphs for making calculations for a given installation is as follows:

Example: Assumed data:

1) Vessel diameter is 14".

2) Product dielectric is 60.

3) Probe type is Model 740A-B072 (72" active length).

4) Desired ZERO point is 12" above the bottom of the active probe end and the 100% level point is 12" below

the gland. Therefore, a 4 foot level change occurs from ZERO to 100% (FULL).

CALCULATIONS

1) At a dielectric of 1 (air), the graph shows the pF/ft. is approximately 4.5 for a 740A-B probe.

2) At a dielectric of 60, the graph shows the pF/ft. to be approximately 53.

3) With product level up to the ZERO level point (remainder of the probe is in the air).

a) Immersed section (1 ft. x 53) =	53 pF
b) Remainder of probe (5 ft. x 4.5) =	22.5 pF
c) Gland value =	24 pF
d) Total ZERO value =	99.5 pF

4) With the product level at the 100% (FULL) point (Lower 5 ft. in product and the upper 1 ft. in air).

a) Immersed section value (5 ft. x 53) =	265 pF
b) Remainder of probe (1 ft. x 4.5) =	4.5 pF
c) Gland value =	24 pF
d) Total 100% value =	293.5 pF

5) The total CAPACITANCE CHANGE is 293.5 minus 99.5 = 194 pF. For quick calculation of CAPACITANCE CHANGE value only, subtract AIR pF/ft. (example 4.5) from PRODUCT pF/ft. (example 53) and multiply by the level difference in feet.
Example: 53 minus 4.5 = 48.5. 48.5 x 4 = 194 pF.

B. For calculation of probes near an "infinite" flat wall or for probes mounted in a large cylindrical vessel but the probe is near the wall of the vessel, calculate the value from the appropriate probe graph using the graph vessel diameter as twice the distance the probe is from the flat wall or vessel wall. Take this value and multiply by .77 (77%). This is not exact but is close enough for all probe pico-farad calculations.

GENERAL NOTES:

1. Conductive Coating Applications:

CAUTION - conductive coatings on the probe will cause an error in measurement. ALWAYS use anti-coating transmitters for continuous measurement and shortstop probes/instruments for point level measurement where products will leave a conductive coating (see "special features", page 7). For continuous measurement with anti-coating transmitters, ALWAYS use a probe or probe mounting that provides the highest pF/ft. gain BUT DOES NOT EXCEED the span of the instrument. Gain can be increased by using our high gain 741A probe or by mounting the probe close to the wall of the tank or vessel.

2. Dielectric/conductivity changes in product:

For continuous measurement of products that change in dielectric/conductivity DO NOT USE any of our capacitance type instruments. For point level only (no adjustable differential) an ON/OFF instrument with a HORIZONTALLY mounted probe or Proximity Plate can be used PROVIDED the instrument is calibrated using the lowest dielectric/conductivity the process will ever be.

3. Where a tank or vessel is non-metallic or lined, a metal process ground MUST BE PROVIDED. This can be accomplished by a customer installed ground rod, using a concentric shield or ground wire wrapped probe (free flowing, non-viscous products ONLY), or installing another bare probe to serve as the ground rod. The least preferred choice is the ground wire wrap. A ground rod should be installed in close proximity to the probe. It should ALWAYS be installed parallel to the probe in low dielectric/non-conductive products. For high dielectric/ conductive products it can be installed anywhere as long as it is NOT ABOVE the tip of the measuring probe.

4. When installing a probe into a vessel through a pipe or nozzle ALWAYS sheath the portion of the probe going through the pipe/nozzle (unless a shortstop probe is used). If a shortstop probe is used (ON/OFF point level only), the shortstop length (not overall length) MUST extend a minimum 4 - 6 inches (preferably 6 inches) out of the pipe/nozzle and into the tank or vessel (see P.S. Sheet for 727A/732A for required length.

CAUTION: Only Models 318A and 5100 with shortstop option can be used with 727A/732A probes.

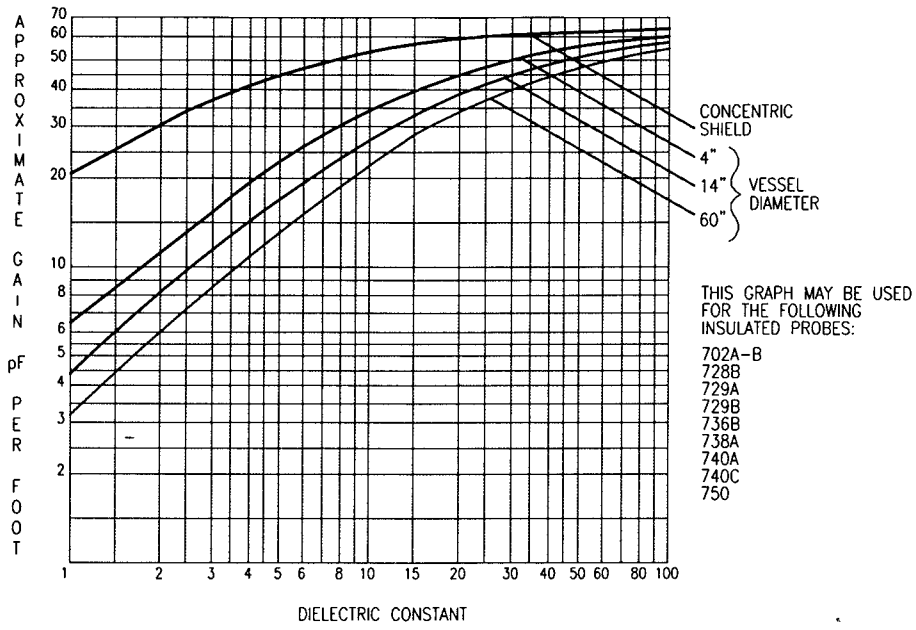
5. Concentric Shield Option of Probes:

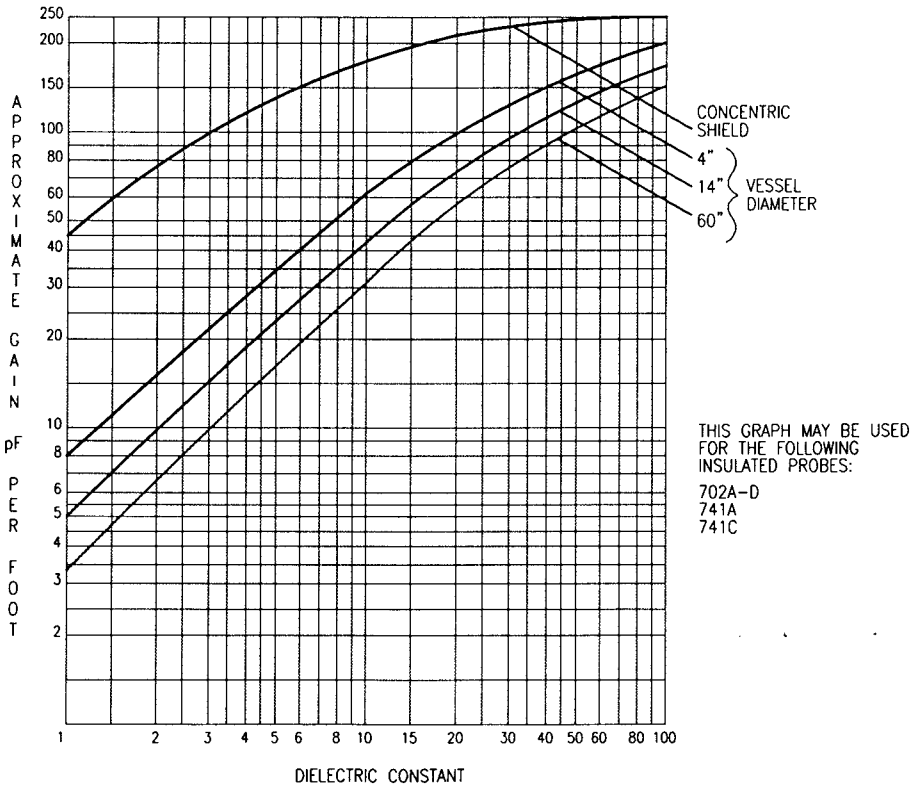
This option can be used for increasing the probe gain in low dielectric materials, linearizing the LEVEL (not volume) signal in a horizontal or non-symmetrical tank, or providing a process ground in a non-metal tank.

CAUTION: concentric shields can ONLY be used in free flowing, non-viscous liquids. Concentric shields are ALWAYS the same length as the probe.

6. Flumes, Weirs, and non-cylindrical or horizontal tanks:

The Model 5000A with "smart chip" option or a Model 7000 can be used for measurement of "flow" in flumes and weirs or volume in non-cylindrical or horizontal tanks. The Model 5000A must be programmed at the factory, therefore, Flume/Weir size/type/minimum-maximum flow must be submitted with order and for tanks, a strapping table is preferred; otherwise submit complete dimensions of tank including type ends/dimensions. The Model 7000 is field programmable.


APPROXIMATE GAIN pF PER FOOT
70
60
50
40
30
20
10
8
6
5
4
3
2
1
2
3
4
5
6
8
10
15
20
30
40
50
60
80
100
DIELECTRIC CONSTANT
CONCENTRIC SHIELD
4"
14"
60"
VESSEL DIAMETER
THIS GRAPH MAY BE USED FOR THE FOLLOWING INSULATED PROBES:
702A-B
728B
729A
729B
736B
738A
740A
740C
750


APPROXIMATE GAIN pF PER FOOT
250
200
150
100
80
60
50
40
30
20
10
8
6
5
4
3
2
1
2
3
4
5
6
8
10
15
20
30
40
50
60
80
100
DIELECTRIC CONSTANT
CONCENTRIC SHIELD
4"
14"
60"
VESSEL DIAMETER
THIS GRAPH MAY BE USED FOR THE FOLLOWING INSULATED PROBES:
702A-D
741A
741C

Bare, Non-Insulated Probes
(NON-CONDUCTIVE PRODUCTS)

Bare, non-insulated, probe calculations are simple, straightforward, mathematical functions. Graphs (curves) for bare probes are actually unnecessary since the "curve" is a straight line. The table below shows the pico-farads per foot for various probes in differing vessel diameters. All values given are for that given probe in that given vessel with AIR surrounding the sensing probe. To determine the pF/ft. for a probe in a given vessel size, multiply the listed value below times the dielectric value of the product being measured. This resultant value is for that probe and vessel with that product **per foot of covered probe. For total capacitance values, remember to add the probe terminal capacitance value (see page 2) to the above obtained figure.**

Pico-Farads per Foot (pF/ft.), Dielectric Value (K) of Air = 1

Vessel Diameter	Probe Type				
	150KB284 737A-B 737A-D	150KB285 737A-A	702A-A	702A-C	702A-Cxxx-x5
Concentric Shield					37 x K
4"	5 x K	6.1 x K	6 x K	7.5 x K	
14"	3.6 x K	4.2 x K	4 x K	5 x K	
60"	2.8 x K	3.1 x K	3 x K	3.5 K	
Gland Capacitance	22 pF	22 pF	12 pF	12 pF	12 pF

Vessel Diameter	Probe Type				
	728B-A	729A 729B	740A-A 740C-A	740A-Axxx-x5 740C-Axxx-x5	741A-A 741C-A
Concentric Shield				15 x K	
4"	7.5 x K		6 x K		7.5 x K
14"	5 x K	4 x K	4 x K		5 x K
60"	3.5 x K	3 x K	3 x K		3.5 x K
Gland Capacitance	40 pF	20 pF	24 pF	24 pF	56 pF

Vessel Diameter	Probe Type		
	741A-Axxx-x5 741C-Axxx-x5	750-A	750-Axxx-x5
Concentric Shield	37 x K		15 x K
4"		6 x K	
14"		4 x K	
60"		3 x K	
Gland Capacitance	56 pF	29 pF	29 pF

K = Dielectric constant of product.

NOTE:
When using the above tables and graphs for determining the span in pico-farads (change in capacitance for a given distance due to the rising product in a vessel) the dielectric constant (K) of the product must be reduced by 1 to compensate for the displaced air.

Capacitance Probe Reference Table

PROBE TYPE	Max. Length	① Max. Temp. °F	① Max. PSI	NPT Mount-ing Thread Size	Gland Capac. pF	⑤ Gain pF/Ft.	Bare O.D.	Ins. O.D.	Teflon Ins.	Poly-ethyl-ene Ins.	Teflon Faced Flange	Maximum Span/Probe Length in a High Dielectric Conductive Product									
												Model 304B	Model 310	Model 314B	Model 318A	Model 158A	Model 167	Model 5100	Model 5400 5400A	Model 5000A	Model 7000
702A-B ⑥	240”	350°	1000#	3/4”	12 pF	60 pF	.218”	.375”	Std.	N/A	N/A	42”	42”	97”	49”	240”	240”	240”	240”	240”	240”
702A-D High Gain ⑥	240”	350°	1000#	3/4”	12 pF	250 pF	.437”	.500”	Std.	N/A	N/A	8”	8”	21”	9”	93”	93”	141”	141”	240”	240”
727A High Temp ④	96”	800°	1000#	1”	- Short-Stop Type -					N/A	N/A	N/A	N/A	N/A	96”	N/A	N/A	96”	N/A	N/A	N/A
728B Heavy Duty ⑥	240”	350°	1000#	1”	40 pF	60 pF	.47”	.75”	Std.	N/A	N/A	37”	37”	92”	44”	240”	240”	240”	240”	240”	240”
729A-B, -D, -G Flexible ⑥	100’	350°	1000#	1”	20 pF	60 pF	.218”	.375”	Std.	N/A	N/A	41”	41”	96”	48”	33’	33’	50’	50’	100’	100’
729A-C, -E, -H Flexible ⑥	100’	150°	1000#	1”	20 pF	65 pF	.218”	.375”	N/A	Std.	N/A	38”	38”	88”	44”	30’	30’	46’	46’	92’	92’
732A ④	96”	350°	1000#	3/4”	- Short-Stop Type -					N/A	N/A	N/A	N/A	N/A	96”	N/A	N/A	96”	N/A	N/A	N/A
736B-A TFE Faced Flange	240”	350°	1000#	N/A	12 pF	60 pF	N/A	.375”	Std.	N/A	Std.	42”	42”	97”	49”	240”	240”	240”	240”	240”	240”
736B-B TFE Faced/Heavy Duty	240”	350°	1000#	N/A	40 pF	60 pF	N/A	.750”	Std.	N/A	Std.	37”	37”	92”	44”	240”	240”	240”	240”	240”	240”
737A Flexible Bare High Temp	100’	600°	3000#	3/4”	22 pF	③	.125”	N/A	N/A	N/A	N/A	-	-	-	-	-	-	-	-	-	-
737A rigid Bare High Temp	96”	600°	3000#	3/4”	22 pF	③	.25”	N/A	N/A	N/A	N/A	-	-	-	-	-	-	-	-	-	-
738A High Temp/Press Ceramic	36”	1000°	3000#	3/4”	25 pF	60 pF	N/A	.375”	N/A	N/A	N/A	36”	36”	36”	36”	36”	36”	36”	36”	36”	36”
739B	- Sanitary Flange Adaption for Probes Listed. See Product Specification Sheets -																				
740A General Purpose ⑥	240”	350°	2000#	3/4”	24 pF	60 pF	.218”	.375”	Std.	N/A	N/A	40”	40”	95”	47”	240”	240”	240”	240”	240”	240”
740C General Purpose, Registered in Canada ⑥	240”	350°	2000#	3/4”	24 pF	60 pF	.218”	.375”	Std.	N/A	N/A	40”	40”	95”	47”	240”	240”	240”	240”	240”	240”
741A High Gain ⑥	240”	350°	600#	3/4”	56 pF	250 pF	.44”	.50”	Std.	N/A	N/A	8”	8”	21”	9”	93”	93”	141”	141”	240”	240”
741C High Gain Registered in Canada ⑥	240”	350°	600#	3/4”	56 pF	250 pF	.44”	.50”	Std.	N/A	N/A	8”	8”	21”	9”	93”	93”	141”	141”	240”	240”
750 Economical General Purpose ⑥	240”	350°	1000#	3/4”	29 pF	60 pF	.218”	.375”	Std.	N/A	N/A	40”	40”	95”	47”	240”	240”	240”	240”	240”	240”
150KB284 Flexible Bare High Temp	100’	1000°	5000#	3/4”	22 pF	③	.125”	N/A	N/A	N/A	N/A	-	-	-	-	-	-	-	-	-	-
150KB285 Rigid Bare High Temp	96”	1000°	5000#	3/4”	22 pF	③	.25”	N/A	N/A	N/A	N/A	-	-	-	-	-	-	-	-	-	-

NOTES:

① MAXIMUM TEMPERATURE AND MAXIMUM PRESSURE CANNOT OCCUR AT THE SAME TIME.

2. N/A means NOT AVAILABLE or NOT APPLICABLE.

③ These are bare probes for use in low dielectric/non-conductive products. Gain is dependent on dielectric constant and can be calculated using table shown on page 5. Maximum span (probe length) depends on calculated value for pF/ft. DO NOT EXCEED SPAN OF INSTRUMENT. Bare probes can also be used for point level **ONLY** (no differential) in high dielectric/conductive products.

④ 727A/732A Short-Stop probes can only be used with Models 318A and 5100 with Short-Stop options.

⑤ Gain shown is for probe in high dielectric/conductive product. See graphs on page 3 for gain in lower dielectric materials.

⑥ Bare, non-insulated probes also available. See applicable P.S. Sheet. Bare probes must be used for measuring low dielectric/non-conductive materials unless using for point level-no differential measurement.

Capacitance Instruments

Model	2 or 4 Wire	SUPPLY			HSG		MTG		Continuous Level Span	Intern. Alarms	On-Off Level Range	Adj. Diff.	Adj. T.D.	Anti-Coating	OUTPUT				Relay Type	PID Control	Hart Comm.	Serial Comm	Special Features
		(5) 26.5 VDC	120 VAC	240 VAC	Expl Prf.	W/T	Direct	Remote							1-5 mADC	4-20 mADC	10-50 mADC	Floating or GD					
158A	4	Op	X	Op	Op	X		X	(8) -2000 pF						Op	X	Op	G					Gen. Purpose Transmitter
167A	2	X			X	X	X		(9) 10-1700 pF					X		X		F					Anti-Coating Transmitter
167B	4		X		X	X	X		(9) 10-1700 pF					X		X		F					Anti-Coating Transmitter
167C	4			X	X	X	X		(9) 10-1700 pF					X		X		F					Anti-Coating Transmitter
5000A	4	Op	X	Op	Op	X		X	10-6000 pF	X	10-6000 pF	X	X			Op		F	DP				Level-Lance Transmitter
304B	4	Op	X	Op	X	X	X			X	15-225 pF	X	X						DP				Gen. Purpose On-Off
310	4	Op	X	Op	Op	X		X		X	20-225 pF	X	X						DP				Gen. Purpose On-Off
314B	4	Op	X	Op	X	X	X			X	15-500 pF	X		X					SP				Duplex On-Off, Anti-Coating
318A-X1	4	Op	X	Op	X	X	X			X	0-260 pF		X						DP				Gen. Purpose On-Off
318A-X2	4	Op	X	Op	X	X	X			X	0-260 pF		X	X					DP				Anti-Coating On-Off (2)
352	4		X	Op	X	X	X			X	Conductivity								DP				Conductivity Type On-Off
5100	4	Op	X	Op	Op	X		X		X	0.2-3000 pF	X	X	Op					DP				Level-Lance On-Off (4)
5400A	4	Op	X	X	Op	X		X		X	0.2-3000 pF	X	X	Op					DP				Level-Lance On-Off Four (3)
7000	4		X	X	Op	X		X	(6) - 6000 pF	OP	(6) - 6000 pF	X	X	Op		Op		F	(7)	Op	Op	Op	Smart Level Control

NOTES:

1 DEFINITIONS:

Supply = Supply power required.

HSG = Housing, Explosion-Proof or Weather tight.

MTG = Mounting, Direct or Remote.

Relay Type = DP means Double Pole Double Throw.
SP means Single Pole Double Throw.

Op = Optional Item.

Floating or GD = F means the output is floating type.
G means the output is grounded type.

(2) Use only with Short-Stop probes 727A and 732A.

(3) 1-4 optional plug-in relay cards for multi-point control.

(4) Short-Stop option available for use with 727A and 732A probes **ONLY** to provide point level anti-coating capability.

(5) 167A Supply requirement is 17-35 VDC.
318A-A, 5000A, 5100 and 5400A DC Supply requirement is 18-30 VDC.

(6) Minimum span when used with anti-coating PFM Transmitter varies from 2 to 30 pF depending on range selected.
Minimum span when used with standard PFM Transmitter is 10 pF.

(7) 2 SP relays or 4 SP relays available.

(8) Minimum span is 10 pF plus 1 pF for each 10 feet of triaxial cable.

(9) Maximum Total Capacitance (terminal, zero suppression & maximum span) is 2000 pF.
Span is 10-1700 pF.
Terminal Capacitance Range is 30 –1000 pF.

Robertshaw
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