US Options

Opening Process

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Contents

1 Overview

Cboe Options Exchanges offer customers the ability to queue orders during the pre-market and regulatory halt periods ("Queuing Period"), after which the Opening Process applicable to each Options Exchange matches crossable interest at a designated Opening Price and transitions to normal trading.

The process by which exchanges transition single leg books from a Queuing Period, whether pre-open or regulatory halt, to normal trading is exchange-specific. BZX, EDGX and C2 Options exchanges use a Midpoint Uncross Opening Process where the opening price at which series open and queued orders are uncrossed is determined by opening markets at away exchanges. The Cboe Options Exchange ("C1") uses a Price Forming Opening Process where the opening prices is determined through a matched contracts maximizing and imbalance minimizing process that is collared by external markets for series for which external markets exist.

A distinct Opening Process applies to Complex instruments on the EDGX, C2 and C1 Options Exchanges. Complex instruments open/re-open in a process that is dependent on the state of the constituent Single Leg Books. Specifically, Complex instruments open/re-open when all constituent Single Leg books transition to the open state and the Complex book opening price is within the synthetic best bid / best offer range formed form the Single Leg book markets. See the 'US Option Complex Book Process' for more detail on the Opening Process used by Complex Instruments.

Both the Midpoint Uncross and Price Forming Opening Processes used for opening Single Leg books are described in this document.

2   Midpoint Uncross Opening Process (BZX, C2, and EDGX)

BZX, EDGX and C2 Options Exchanges use a Midpoint Uncross Opening Process to open single leg books at the start of trading, and to re-open after the intraday receipt of an underlying Regulatory Halt from the underlying primary exchange puts a series back into a Queuing Period until unhalted by the primary exchange.

2.1   Queuing Period

For both the start of trading and regulatory halts, a Queuing Period precedes the open/re-open. Figure 1 and Figure 2 below illustrate the Opening Process for both start of trading and regulatory halts:

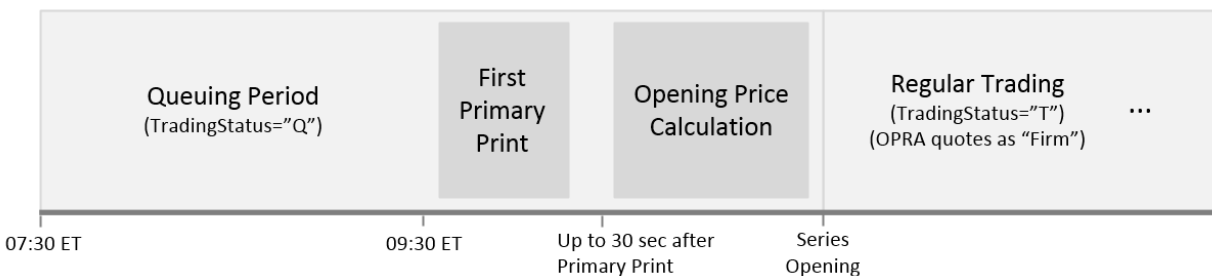**Figure 1 -** *Start of day Midpoint Uncross opening*

Figure 2 - *Regulatory Halt Midpoint Uncross re-opening*

During the Queuing Period, Limit on Open ("LOO"), Market on Open ("MOO"), and non-IOC Limit Orders are accepted into single leg pre-open books for queuing. IOC orders submitted during a Queuing Period are rejected. Queued orders may be cancelled or modified at any time during the Queuing Period up to the point of the Opening Price calculation.

During the Queuing Period, the book may appear crossed as observed on the PITCH data feed. Opening Triggers

For start of trading openings the Queuing Period begins at a scheduled time (7:30 AM ET). The trigger to open a series at the start of trading is the first observation of an underlying print of at least one round lot in size on the primary exchange after a designated time (9:30 AM ET).

For regulatory halts, the Queuing Period begins at the observation time of an underlying halt issued by the primary exchange. On receipt of an underlying halt, all associated single leg series and their

dependent complex series transition to the Queuing state (Queuing Period). Series remain in the Queuing state until the observation of the opening trigger, which in the case of regulatory halts is when a regulatory halt has been lifted by the primary exchange.

2.2 Opening Price Determination

After the Opening Trigger is observed, the Opening Price is computed, after which the book is uncrossed at the Opening Price and Regular Trading commences.

The Opening Price is the midpoint of the NBBO, rounded down to the nearest full penny for half-cent midpoints. If the one or both sides of the NBBO has not been observed, there is no valid Opening Price and the series. The system will remain in the Queuing State until a valid NBBO is observed.

At the Exchange discretion, in the event that a valid NBBO has not been observed for an excessive amount of time, the Opening Price may be assigned the last regular way trade, which may include the previous day's close.

2.3 Market Width Check

Prior to uncrossing a book at a computed Opening Price, the width of the prevailing NBBO is checked against maximum width values provisioned as a function of the NBB as shown in Table 3 below:

Table 1 - *Midpoint uncross maximum width vs NBB*

National Best Bid (NBB)	Max Width
Below $2.00	$0.50
$2.00 to $5.00	$0.80
Above $5.00 to $10.00	$1.00
Above $10.00 to $20.00	$1.60
Above $20.00 to $50.00	$2.00
Above $50.00 to $100.00	$3.00
Above $100.00	$4.00

If the NBBO width exceeds the Max Width per Table 1 above, the series stays in the Queuing state until the NBBO width falls back within the Max Width.

At the Exchange discretion, in the event that the width of the NBBO remains above the Max Width for an excessive amount of time and markets are orderly, the max width enforcement may be disabled.

2.4   Opening Uncross

After the Opening Trigger is observed, a valid Opening Price is computed and the NBBO check passes (or is disabled) the book is uncrossed at the Opening Price prior to transition to Regular Trading.

If there are no orders crossable at the Opening Price, orders in the queued book are introduced into the continuous book in timestamp order and normal order handling according to order type, routing instruction, and time-in-force instructions identified on the order.

If there exists crossable orders at the Opening Price, orders that are priced equal to or more aggressively than the Opening Price will be matched at the Opening Price based on either time priority for BZX Options, customer priority/pro rata allocation for EDGX Options, or size pro rata allocation for C2 Options.

LOO and MOO order quantities not filled in the Opening Uncross are cancelled back. Other order quantities not filled In the Opening Uncross match will be rolled into the Regular Trading book in time priority and handled according to the order type, routing instruction and time-in-force instructions identified on the order.

2.5   Risk Limits During the Opening

During the Opening Process for both start of trading and regulatory halts re-opening, Risk Limits are in effect. However, within the context of a series opening, executions in the matching phase that cause a Risk Limit to be exceeded will not be stopped. In other words, Risk Limit trips will not prevent a series from opening. As a result Risk Limits can be exceeded as a result of a series opening. Immediately after the series opening in which the Risk Limit was tripped (exceeded), associated live orders are cancelled, from both simple and complex series books still in the Queuing state and those that have transitioned to Regular Trading.

New orders received after the Risk Limit is tripped and before a risk reset operation is effected through FIX/BOE are rejected.

Mass Cancel functionality exists in the pre-open and regulatory halt queuing periods, the same in Regular Trading.

2.6 Non-Regulatory Halt Re-Opening

Figure 3 below illustrates the timeline associated with a non-regulatory halt. In the event a non-regulatory halt is issued by the Cboe Exchange (BZX, EDGX or C2), all open orders are cancelled immediately. As a result, open orders at the time of a non-regulatory halt will not be eligible to be rolled to continuous trading post-halt. All order received after the occurrence of a non-regulatory halt and before the re-open will be rejected.

Figure 3 - *Non-Regulatory Halt*
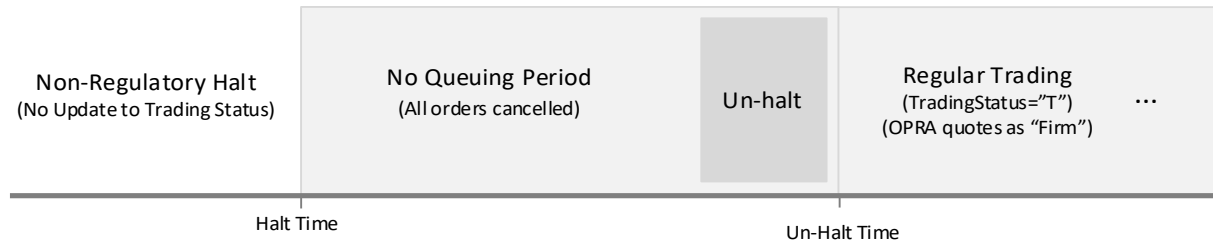
The following enumerate exchange actions in various non-regulatory halt scenarios:

1. If a non-regulatory halt is issued during Regular Trading, affected series will transition directly to Regular Trading following the non-regulatory halt being lifted.

2. If a non-regulatory halt is issued while a series is in the Queuing Period prior to the start of Regular Trading, and the opening trigger does not occur prior to the lifting of the non-regulatory halt, affected series will be returned to the Queuing state following the non-regulatory halt being lifted.

3. If a non-regulatory halt is issued while a series is in the Queuing Period prior to the start of Regular Trading, and the opening trigger occurs prior to the lifting of the non-regulatory halt, affected series will transition directly to Regular Trading following the non-regulatory halt being lifted.

4. If a non-regulatory halt is issued after the occurrence of the opening trigger, but before the series has successfully transitioned to Regular Trading, affected series will transition directly to Regular Trading following the non-regulatory halt being lifted.

5. If the non-regulatory halt is issued while a series is in a Queuing Period at the start of trading and a regulatory halt is received prior to the non-regulatory halt being lifted, affected series will be return to the Queuing Period after both the non-regulatory and regulatory halts are lifted.

6. If the non-regulatory halt is issued while a series is in a Queuing Period at the start of trading and a regulatory halt is received and lifted prior to the non-regulatory halt being lifted, affected series will transition directly to Regular Trading following the non-regulatory halt being lifted.

3   Price Forming Opening Process (C1 Only)

A price forming Opening Process is used on the Cboe Options Exchange ("C1") to open proprietary and Multilist option series both at the beginning of trading sessions and to re-open after regulatory halts.

A select number of proprietary classes trade in an extended hours session referred to as Global Trading Hours ("GTH"). Classes that trade GTH also trade Regular Trading Hours ("RTH"). Queuing for the RTH session for series in these classes starts while the GTH session is active, and as a result, there exists a continuous trading book (GTH) while the RTH book is in a queuing state. These classes referred to as GTH Prop Classes, leverage the presence of the continuous book for placement of collars on the RTH Opening.

The C1 price forming Opening Process applies to the following four distinct categories of classes traded on C1:

Table 2 - *C1 options class categories*

Option class category	Description
Multilist	Classes for which away markets and an ABBO exists. Start of trading open at the beginning of Regular Trading Hours ("RTH").
No-GTH Proprietary	Proprietary classes that do not trade in Global Trading Hours ("GTH"). Start of trading open at the beginning of RTH. There is no continuous book coincident with the pre-open Queuing book.
GTH-Enabled Proprietary	Proprietary classes that trade both GTH and RTH. The Queuing period for GTH and RTH sessions start at the same time (2:00 AM ET). The GTH session opens at 3:00 AM ET, which is open for trading until the trading GTH session and queuing RTH session are brought together for the RTH opening at approximately 9:30 AM ET.
SOQ Constituent Series	A subset of GTH-Enabled Proprietary Classes that on specific dates are constituent series of a Volatility Derivative expiration Special Opening Quote ("SOQ"). Constituent series RTH opening uses a restrictive form of the Opening Process known as the Volatility Opening Process.

For all class categories, the following applies:

- Matched Trade Prevention ("MTP") is not in-effect during the matching phase of crossed-book openings.

- Risk limits are in-effect during the Opening Process. However, risk limit trips during the matching phase of crossed-book series openings will not interrupt the opening of that series.

- Opening triggers, specific to each category, must be observed in order to initiate the opening process (defined in respective sections below).

- The Volume Maximizing Imbalance Minimizing ("VMIM") algorithm is used to determine the opening price for crossed books, with category-specific collars and other constraints (defined below).

- For a period of time during the queuing period in all class categories, Auction Update messages are disseminated on PITCH, TOP and Opening Process Data Feeds that provide expected opening price, size and imbalance information (see 'VMIM Algorithm' and 'Auction Update Message' sections below for more detail on Auction Update message content).

- For SOQ Constituent Series, a cutoff time exits after which new Limit On Open ("LOO") and Market On Open ("MOO") orders are rejected, existing LOO and MOO orders cannot be modified or cancelled, and other post-cutoff constraints. See Section 3.9.3 - Volatility Opening Cutoff Time for details).

3.1 Volume Maximizing Imbalance Minimizing ("VMIM") Algorithm

The opening price for a series, as well as prices disseminated in Auction Update messages during the Queuing Period, are computed using the Volume Maximizing Imbalance Minimizing ("VMIM") algorithm for both uncollared and collared openings. The VMIM algorithm is summarized as follows:

1. Select the price that maximizes the number of contracts matched on the open.

2. If there are multiple prices at which the same maximum contracts will be matched, select the price that minimizes the absolute imbalance, which is defined as the cumulative contracts at or above the price to buy minus the cumulative contracts at or below the price to sell.

3. If there are multiple prices at which the same maximum contracts will be matched and with the equivalent minimized absolute imbalance, and the imbalance is not zero, use the sign of the imbalance to select either the highest of the prices (positive imbalance) or the lowest of the prices (negative imbalance)

4. If there are multiple prices at which the same maximum contracts will be matched and zero imbalance, select the price closest to the Volume-Based Tie Breaker ("VBTB"), which is set to the midpoint of the opening collar.

Numerical examples illustrating the VMIM algorithm in several scenarios are presented in '*Appendix 1 – VMIM Algorithm Examples*'.

3.2   Opening Information Dissemination

3.2.1   Queuing Period and Opening Information Dissemination Start Times

Table 3 below presents the start of the Queuing Period and the time at which Auction Update message dissemination begins by option class category. The start of the Queuing Period is the time at which the system begins accepting orders for queuing.

Table 3 - *Queuing Period start times by option class category*

Option Class Category	Queuing Period Start Time	Start of Auction Update Dissemination
Multilist	02:00 AM ET	02:00 AM ET
No-GTH Proprietary	02:00 AM ET	02:00 AM ET
GTH-Enabled Proprietary	GTH: 02:00 AM ET RTH: 02:00 AM ET	GTH: 02:00 AM ET RTH: 07:00 AM ET

3.2.2   Queuing Period Expected Opening Information

During a portion of the Queuing Period (defined in each class category section below) Auction Update messages are disseminated on TOP, PITCH and Opening Process data feeds with information regarding expected opening price, size and imbalances. Table 4 below presents fields of the Auction Update message:

Table 4 - *Auction Update message fields*

Field	Description
Auction-Only Price	Uncollared VMIM price computed on the queuing book only.
Reference Price	Collared VMIM price computed on the queuing book only.
Buy Contracts	Cumulative Buy contracts at the Reference Price and above.
Sell Contracts	Cumulative Sell contracts at the Reference Price and below.
Indicative Price	Collared VMIM price computed on the combined queuing book and the continuous book. For opening scenarios that do not include a continuous book trading (i.e., Multilist and non-GTH Proprietary) the Indicative Price and the Reference Price are identical.
Opening Condition	Indication of the state of the opening process. "Would open" indicates that width checks and collars will not prevent opening. "Need quote to Open" indicates that the width check failed and the opening will not occur until the relevant market width narrows. "Need more buyers" and "Need more sellers" are used specifically in the context of Volatility Openings where unfilled Market order contracts and collar violations prevent series openings.

3.2.3   Opening Price and Size

At the conclusion of a successful series opening an Auction Summary message is disseminated on TOP, PITCH and Opening Process data feeds with summary trade information. The fields include the Auction Type, Price, and Contracts executed in the related Opening.

3.3 Maximum Width Checks

Maximum Composite Width ("MCW") checks are applied to all option class category openings. Width checks prevent a given series from opening if the prevailing market for the series is too wide. The MCW is determined through a table lookup vs. the MCW Reference price, which is defined in Table 5 below for each Option Class Category.

Table 5 - *Maximum Width Reference and Composite Width by option class category*

Option Class Category	Max Composite Width Ref Price	Composite Width
Multilist	Higher of MM-BB and ABB	Difference between 1) Higher of MM-BB and ABB, and 2) Lower of MM-BO and ABO
No-GTH Proprietary	MM-BB	Difference between MM-BO and MM-BB
GTH-Enabled Proprietary	CB-BB	Difference between CB-BO and CB-BB

Table 6 below defines the MCW as a function of the MCW Reference Price:

Table 6 – *Maximum Composite Width vs. Reference Price*

Max Composite Width Ref Price	Max Composite Width
0.00 – 100.00	10.00
100.01 – 200.00	16.00
>= 200.01	24.00

A series will not open if the Composite Width exceeds the MCW. The system will periodically retry series openings until the width check succeeds. If the Composite Width exceeds the MCW, an Auction Update message is disseminated with an Opening Condition value of "Q", indicating "Need quote to open".

3.4 Opening Collars

Opening collars are applied to ensure that the Opening Price falls within a reasonable distance from the Opening Collar Midpoint Price, and in the case of Multilist, to ensure that the Opening Price does not violate the Away Market Best Bid and Offer ("ABBO"). The Opening Collar Width ("OCW") is determined through a table lookup vs. the OCW Reference Price, which is defined in Table 7 below for each Option Class Category. The OCW is centered on the Opening Collar Midpoint ("OCMP") to determine upper and lower Opening Collar Prices.

Table 7 – *Opening Collar Width Reference, Midpoint and Prices by option class category*

Option Class Category	Ref Price	Opening Collar Midpoint	Opening Collar Prices
Multilist	Higher of MM-BB and ABB	Midpoint between 1) Higher of MM-BB and ABB, and 2) Lower of MM-BO and ABO	Upper: Lower of (OCMP+1/2 OCW) and ABO Lower: Higher of (OCMP-1/2 OCW) and ABB
No-GTH Proprietary	MM-BB	Midpoint of MM-BB/BO	Upper: OCMP + 1/2 OCW Lower: OCMP - 1/2 OCW
GTH-Enabled Proprietary	GTH: MM-BB RTH: CB-BB	GTH: Mid of MM-BB/BO RTH: Mid of CB-BB/BO	Upper: OCMP + 1/2 OCW Lower: OCMP - 1/2 OCW

Note that the Volume-Based Tie Breaker ("VBTB") for the VMIM algorithm as presented in Section 3.1 - Volume Maximizing Imbalance Minimizing ("VMIM") Algorithm – above is set to the Opening Collar Midpoint for all Option Class Categories.

Table 8 below defines the OCW as a function of the OCW Reference Price:

Table 8 – *Opening Collar Width vs. Reference Price*

Opening Collar Width Ref Price	Opening Collar Width
0.00 – 1.99	0.50
2.00 – 5.00	0.80
5.01 – 10.00	1.00
10.01 – 20.00	2.00
20.01 – 50.00	3.00
50.01 – 100.00	5.00
100.01 – 200.00	8.00
>= 200.01	12.00

With the exception of Volatility Openings, series will open at the VMIM price within prevailing collar prices despite the uncollared VMIM falling outside of the collar range. For Volatility Openings, if the uncollared VMIM price falls outside of the collar range, the series will not open and Auction Update messages will be disseminated with the Opening Condition set to "B" (Need more buyers) or "S" (Need more sellers) as needed to resolve the imbalance resulting in the collar violation.

3.5   Opening Triggers

For each option class category, Opening Triggers are used to transition series from Trading State "Q" (Queuing) to Trading State "R" (Opening Rotation). Trading State "R" is an intermediate state to indicate that that the system is attempting to open the series. Series will when transition to Trading State "T" (Trading) upon successful opening. Table 9 below defines the Opening Trigger for each option class category and session:

Table 9 - *Opening Trigger by option class category and session*

Option Class Category	Opening Trigger
Multilist	RTH: Observation of first print in the underlying from any away exchange after 09:30 AM ET. Note the print is not restricted to the primary exchange for the underlying.
No-GTH Proprietary	RTH: Observation of the first underlying index after 09:30 AM ET
GTH-Enabled Proprietary	GTH: Time-based RTH: Observation of the first underlying index after 09:30 AM ET

3.6 Multilist Opening

Figure 4 below illustrates Multilist class category Opening Process on the C1 Exchange:

Figure 4 - *Multilist Opening Process*
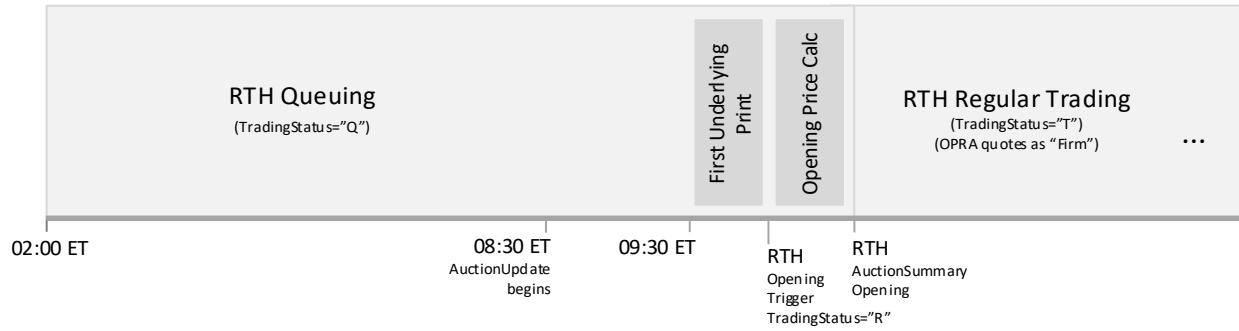
3.7 No-GTH Proprietary Opening

Figure 5 below illustrates No-GTH Proprietary class category Opening Process on the C1 Exchange:

Figure 5 - *No-GTH Proprietary opening process*

3.8 GTH-Enabled Proprietary Opening

Figure 6 below illustrates GTH Proprietary class category Opening Process on the C1 Exchange. Note GTH Proprietary have time-triggered GTH openings followed by the RTH opening after 9:30 AM ET at which the continuously trading GTH book is combined with the queuing RTH book with a VMIM opening price calculation, at which time the GTH session stops and the RTH session begins for each series belong to GTH-enabled Proprietary classes.

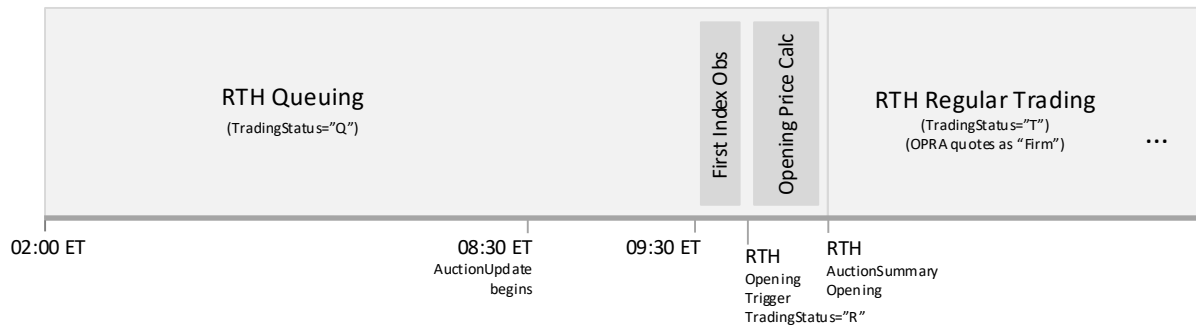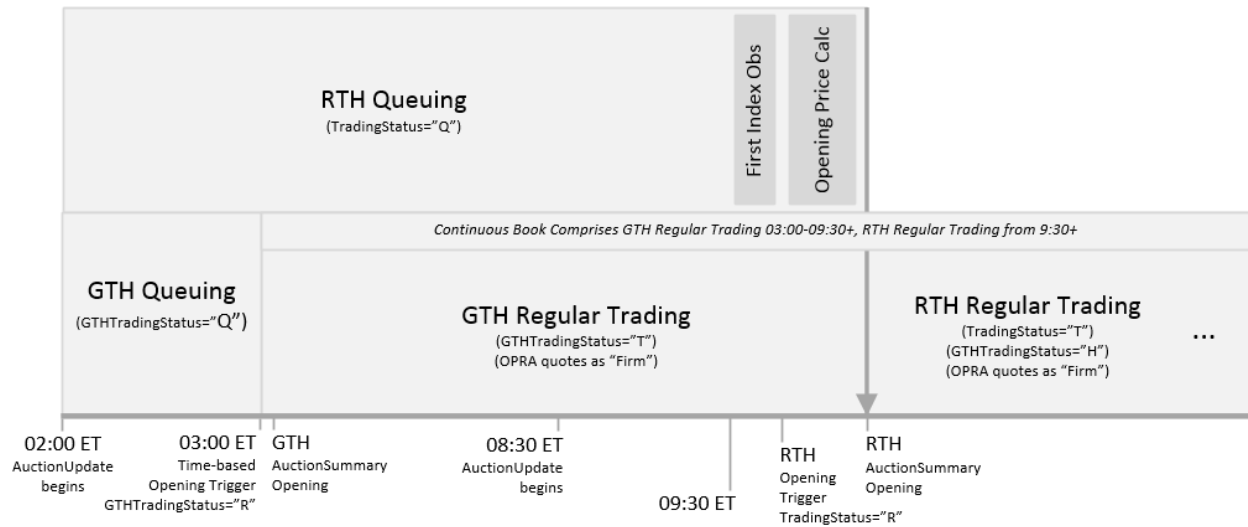**Figure 6 -** *GTH-Enabled Proprietary opening process*

3.9 Volatility Opening (Constituent Series)

Constituent Series of a Volatility Opening are series of GTH-enabled proprietary classes that participate in the special RTH opening used in the Volatility Expiration "Special Opening Quote". These series open in the GTH session the same as all other GTH-enabled proprietary series. The RTH opening of Constituent Series differs from RTH opening of other GTH-enabled proprietary series in the following ways:

- Tighter Maximum Composite Width values for Volatility Openings (defined below)

- Tighter Opening Collar Width values for Volatility Openings (defined below)

- Series do not open if the uncollared VMIM price exceeds prevailing collar prices. Auction Update messages are disseminated with "Need more buyers"/"Need more sellers" indications as necessary to bring the opening price back to within prevailing collars.

- Series do not open if there are unfilled Market Order contracts. Auction Update messages are disseminated with "Need more buyers"/"Need more sellers" indications as necessary to fill unfilled Market Order contracts.

- A time point prior to the Opening Trigger of the RTH opening known as the "Cutoff Time" exists after which certain order type constraints are in-effect (defined below).

3.9.1 Volatility Opening Maximum Composite Widths

Table 10 below defines Maximum Composite Width values in-effect for Volatility Openings

Table 10 – *Volatility Opening specific Maximum Composite Width vs. Reference Price*

Max Composite Width Ref Price	Max Composite Width
0.00 – 0.50	0.60
0.51 – 1.99	1.00
2.00 – 5.00	1.60
5.01 – 10.00	2.00
10.01 – 20.00	2.50
20.01 – 30.00	4.00
30.01 – 40.00	5.00
40.01 – 50.00	6.00
50.01 – 100.00	10.00
100.01 – 200.00	16.00
>= 200.01	24.00

3.9.2 Volatility Opening Collar Widths

Table 11 below defines Opening Collar Width values in-effect for Volatility Openings

Table 11 – *Volatility Opening specific Opening Collar Width vs. Reference Price*

Opening Collar Width Ref Price	Opening Collar Width
0.00 – 0.25	0.25
0.26 – 0.50	0.30
0.51 – 1.00	0.35
1.01 – 1.99	0.40
2.00 – 5.00	0.60
5.01 – 10.00	0.70
10.01 – 20.00	1.00
20.01 – 30.00	1.80
30.01 – 40.00	2.40
40.01 – 50.00	3.00
50.01 – 100.00	6.00
100.01 – 200.00	9.00
>= 200.01	14.00

3.9.3 Volatility Opening Cutoff Time

A cutoff time [N] seconds prior to the scheduled RTH opening time (9:30 AM ET) exists for Volatility Openings after which several constraints and order type behaviors are enforced, including the introduction of a Volatility Opening specific order type Late Limit on Open ("LLOO"). The following summarizes the constraints in-effect after the cutoff time:

- LOO and MOO orders are rejected

- Existing LOO and MOO orders cannot be cancelled or modified

- Late Limit on Open ("LLOO") orders are accepted.

  o LLOO orders are a special form of Limit order that work at the midpoint of the continuous book (i.e., GTH session midpoint) if the Limit price of the order is more aggressive than the midpoint of the continuous book. The working price will slide more aggressive as the midpoint of the continuous book changes, but never less aggressive, up to the original limit price of the LLOO order.

    ▪ For FIX order entry protocol, the *TimeInForce* (59) field is set to 2 to specify "At the Open", and the *ExecInst* (18) field is set to "r" for "Late".

    ▪ For BOE order entry protocol, the *TimeInForce* optional field is set to 2 to specify "At the Open", and the *ExecInst* optional field is set to "r" for "Late".

  o LLOO orders are rejected if submitted prior to the cutoff time.

  o LLOO order price and size can be modified with associated loss of time and possibly price priority depending on the current midpoint of the continuous book.

  o LLOO orders unfilled in the opening are cancelled back.

- RTH-only Limit Orders submitted after the cutoff time are handled as LLOO orders for purpose of the opening.

- An RTH-only Limit Order submitted prior to the cutoff but modified after the cutoff are handled as LLOO orders after the modification.

  o Unfilled RTH-only Limit Order contracts that were handled as LLOO orders roll to the continuous book as the originally submitted Limit Orders at the originally submitted Limit price.

- RTH-only Market Orders submitted prior to the cutoff are handled as MOO orders.

- RTH-only Market Orders submitted after the cutoff are rejected.

Appendix 1 – VMIM Algorithm Examples

In Example 1 below, the price at which the most contracts are matched is $1.96 (400 contracts) and as a result the equilibrium price is $1.96. Since there is only a single price that maximizes the matched contracts, that price is selected as the VMIM price.

Example 1 – *Simple VMIM price calculation*

CumBid	BidQty	Price	AskQty	CumAsk	Match	Imb
0	0	mkt (bid)				
0		2.00	100	8,500	0	(8,500)
0		1.99	1,000	8,400	0	(8,400)
100	100	1.98	3,000	7,400	100	(7,300)
200	100	1.97	4,000	4,400	200	(4,200)
700	**500**	**1.96**	**100**	**400**	**400**	**300**
1,700	1,000	1.95	100	300	300	1,400
2,200	500	1.94	100	200	200	2,000
3,200	1,000	1.93	100	100	100	3,100
4,400	1,200	1.92		0	0	4,400
4,900	500	1.91		0	0	4,900
5,000	100	1.90		0	0	5,000
		mkt (ask)	0	0		

In Example 2 below, multiple prices are associated with the same maximum number of matched contracts. In this scenario the price with the minimum imbalance is selected as the VMIM price. In this example, both the $1.97 and $1.96 price levels result in 400 contracts being executed. Since there is a 4,000 contract sell imbalance at the $1.97 price level and a zero imbalance at the $1.96 price level, the system will select $1.96 as the VMIM price.

Example 2 – *Imbalance minimizing price*

CumBid	BidQty	Price	AskQty	CumAsk	Match	Imb
0	0	mkt (bid)				
0		2.00	100	8,500	0	(8,500)
0		1.99	1,000	8,400	0	(8,400)
0		1.98	3,000	7,400	0	(7,400)
400	400	1.97	4,000	4,400	400	(4,000)
400		**1.96**	**100**	**400**	**400**	**0**
1,400	1,000	1.95	100	300	300	1,100
1,900	500	1.94	100	200	200	1,700
2,900	1,000	1.93	100	100	100	2,800
4,100	1,200	1.92		0	0	4,100
4,600	500	1.91		0	0	4,600
4,700	100	1.90		0	0	4,700
		mkt (ask)	0	0		

In Example 3 below, which includes market orders to buy 200 contracts and to sell 100 contracts, multiple prices are associated with the same maximum number of matched contracts and the same absolute non-zero imbalance. In this case the VMIM algorithm selects the highest price in the range since the sign of the imbalance is positive, which is $1.97

Example 3 – *Imbalance sign-based tie breaker*

CumBid	BidQty	Price	AskQty	CumAsk	Match	Imb
200	200	mkt (bid)				
200		2.00	100	4200	200	(4,000)
200		1.99	1,000	4100	200	(3,900)
200		1.98	3,000	3100	200	(2,900)
200		**1.97**		**100**	**100**	**100**
200		1.96		100	100	100
200		1.95		100	100	100
700	500	1.94		100	100	600
1,800	1,100	1.93		100	100	1,700
3,000	1,200	1.92		100	100	2,900
3,500	500	1.91		100	100	3,400
3,600	100	1.90		100	100	3,500
		mkt (ask)	100	100		

In Example 4 below is the same as Example 3 above except that the quantity of market orders is 100 to buy and sell. The result is that there is a set of prices (1.95, 1.96 and 1.97) that all maximize the matched contracts and minimize the imbalance, which is zero. Further, assume that the prevailing collar midpoint is $1.90. The VMIM algorithm selects the price closest the to the Volume-Based Tie Breaker, which is the collar midpoint ($1.90). As a result, the opening price is $1.95.

Example 4 – *Volume-based tie breaker*

CumBid	BidQty	Price	AskQty	CumAsk	Match	Imb
100	100	mkt (bid)				
100		2.00	100	4200	100	(4,100)
100		1.99	1,000	4100	100	(4,000)
100		1.98	3,000	3100	100	(3,000)
100		1.97		100	100	0
100		1.96		100	100	0
100		**1.95**		**100**	**100**	**0**
600	500	1.94		100	100	500
1,700	1,100	1.93		100	100	1,600
2,900	1,200	1.92		100	100	2,800
3,400	500	1.91		100	100	3,300
3,500	100	1.90		100	100	3,400
		mkt (ask)	100	100		

Example 5 below shows a $0.30 wide collar centered on the midpoint price of $0.85. The matched contract maximizing price of $1.10 exceeds the upper collar price of $1.00. As a result, the VMIM algorithm restricts focus to the prices within the collar range. In this example, both $0.95 and $1.00 both maximize matched contracts (10) with minimized absolute imbalance (10). As a result, the sign of the imbalance (positive) is used to select the upper price of $1.00 as the opening price.

Example 5 – *Collared price with positive imbalance sign-based tie-breaker*

CumBid	BidQty	Price	AskQty	CumAsk	Match	Imb
20	20	mkt (bid)				
20		1.10	10	20	20	0
20		1.05		10	10	10
20		1.00		10	10	10
20		0.95	10	10	10	10
20		0.90		0	0	20
20		0.85		0	0	20
20		0.80		0	0	20
20		0.75		0	0	20
20		0.70		0	0	20
20		0.65		0	0	20
20		0.60		0	0	20
		mkt (ask)	0	0		

In Example 6 below, the matched contract maximizing price of $0.60 violates the lower collar price of $0.70. As a result the VMIM, the VMIM algorithm restricts focus to the prices within the collar range. In this example the prices from $0.70, $0.75 and $0.80 all maximize matched contracts with minimized absolute imbalance of negative 10. As a result, the sign of the imbalance (negative) is used to select from the lower price of $0.70 as the opening price.

Example 6 – *Collared price with negative imbalance sign-based tie-breaker*

CumBid	BidQty	Price	AskQty	CumAsk	Match	Imb
0	0	mkt (bid)				
0		1.10		20	0	(20)
0		1.05		20	0	(20)
0		1.00		20	0	(20)
0		0.95		20	0	(20)
0		0.90		20	0	(20)
10	10	0.85		20	10	(10)
10		0.80		20	10	(10)
10		0.75		20	10	(10)
10		0.70		20	10	(10)
10		0.65		20	10	(10)
20	10	0.60		20	20	0
		mkt (ask)	20	20		

In Example 7 below, all prices shown result in the same number of matched contracts but only the prices $0.65, $0.70 and $0.75 minimize the absolute imbalance, and in this case the imbalance associated with these prices is zero. The VMIM algorithm selects the price within the collar that is closest to the Volume-Based Tie Breaker, which is the midpoint of the prevailing collar ($0.85). As a result, the selected opening price is $0.75.

Example 7 – *Collared price with zero imbalance volume-based tie-breaker*

CumBid	BidQty	Price	AskQty	CumAsk	Match	Imb
20	20	mkt (bid)				
20		1.10		25	20	(5)
20		1.05		25	20	(5)
20		1.00		25	20	(5)
20		0.95		25	20	(5)
20		0.90		25	20	(5)
20		0.85		25	20	(5)
20		0.80	5	25	20	(5)
20		0.75		20	20	0
20		0.70		20	20	0
20		0.65		20	20	0
30	10	0.60		20	20	10
		mkt (ask)	20	20		

Revision History

Version	Date	Description
2.0.0	11/16/18	Version 1.x retired in favor of new format and to include support for Cboe Options Exchange.
2.0.1	01/22/19	Updated presentation of Maximum Composite Width and Opening Collar Width to include values vs. reference price tables and specific value in-effect for Volatility Openings. Added examples of calculation of collared opening prices. Added detail for post-cutoff time order type constraints for Volatility Openings.
2.0.2	01/30/19	Added VMIM algorithm examples showing the imbalance sign based price selection in both uncollared and collared scenarios. Moved numerical VMIM examples to an Appendix.