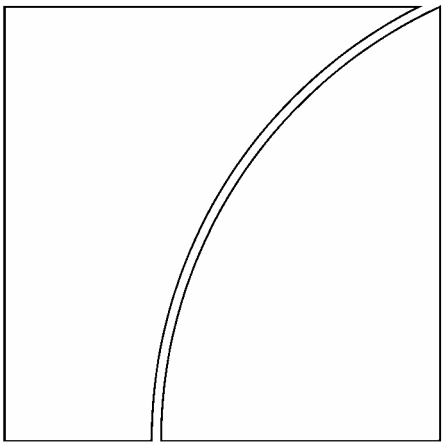
Basel Committee
on Banking Supervision



An internal model-based approach to market risk capital requirements

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BANK FOR INTERNATIONAL SETTLEMENTS

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OVERVIEW

1. In April 1993 the Basle Committee on Banking Supervision[1] issued for comment by banks and financial market participants a paper entitled "The supervisory treatment of market risks". That paper set out a framework for applying capital charges to the market risks incurred by banks, defined as the risk of losses in on- and off-balance-sheet positions arising from movements in market prices.[2] The Committee has now concluded its review of the comments received and is issuing a revised package of proposals. This paper, which forms a part of that package, provides a commentary on Part B of the accompanying planned Supplement to the Capital Accord (referred to hereafter as "the Supplement").

2. The proposals for applying capital charges to market risks issued in April 1993 envisaged the use of a standardised methodology to measure market risks as a basis for applying capital charges to open positions. The industry's comments on these proposals raised a number of issues which the Committee felt to be worthy of a considered response. These were, in brief, that:

- the proposals did not provide sufficient incentive to improve risk management systems because they did not recognise the most accurate risk measurement techniques;
- the proposed methodology did not take sufficient account of correlations and portfolio effects across instruments and markets, and generally did not sufficiently reward risk diversification;
- the proposals were not sufficiently compatible with banks' own measurement systems.

3. In considering the industry's comments, the Committee took account of the fact that the risk management practices of banks have developed significantly since the initial proposals were formulated in the early 1990s. In particular, the Committee is conscious of the

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1 The Basle Committee on Banking Supervision is a Committee of banking supervisory authorities which was established by the central-bank Governors of the Group of Ten countries in 1975. It consists of senior representatives of bank supervisory authorities and central banks from Belgium, Canada, France, Germany, Italy, Japan, Luxembourg, Netherlands, Sweden, Switzerland, United Kingdom and the United States. It usually meets at the Bank for International Settlements in Basle, which supplies its Secretariat.

2 The risks covered by the proposed framework were: (a) the risks in the securities trading book of debt and equity securities and related off-balance-sheet contracts and (b) foreign exchange risk. The Committee has now decided to incorporate commodities risk too.

need to ensure that regulatory requirements do not impede the development of sound risk management by creating perverse incentives. Many banks argued that their own risk management models produced far more accurate measures of market risk, adding that there would be costly overlaps if they were required to calculate their market risk in two different manners.

4. During 1994, therefore, the Committee investigated the possible use of banks' proprietary in-house models for the calculation of market risk capital as an alternative to a standardised measurement framework. The results of this study were sufficiently reassuring for it to envisage the use of internal models to measure market risks, subject to a number of carefully defined criteria. The precise requirements which the Committee is planning to apply to banks which use their models as a basis for calculating market risk capital are set out in Part B of the Supplement. The purpose of this paper is to explain some of the thinking behind those criteria.

5. The Committee has devoted a considerable amount of time and effort in studying the models used by banks and the measures of risk that they produce. In preliminary testing conducted in the second half of 1994, a number of banks in the major centres were asked to run an identical portfolio through their models and the results were examined for consistency. This process was extremely helpful in identifying methodological differences and in providing empirical support for certain common statistical parameters. This testing exercise is described further in Section II of the paper.

6. The proposed approach for a models-based supervisory capital requirement is based on the definition of a series of ***quantitative*** and ***qualitative*** standards that banks would have to meet in order to use their own systems for measuring market risk, while leaving a necessary amount of flexibility to account for different levels of detail in the systems.

- The ***quantitative*** standards are expressed as a number of broad risk measurement parameters for banks' internal models, together with a simple rule for converting the models-based measure of exposure into a supervisory capital requirement.
- The ***qualitative*** standards are designed to ensure that banks' measurement systems are conceptually sound and that the process of managing market risks is carried out with integrity. In addition, it is necessary to define the risks that need to be covered, the appropriate guidelines for conducting stress tests, as well as to give guidance on validation procedures for examiners and auditors charged with independently reviewing and validating banks' internal models.

7. As set out in the Supplement, the Committee intends to allow a transition period from the release of the final version of the Supplement before the market risk rules come into full force (i.e. until the end of 1997). During this period, the Committee is considering further testing for those banks planning to use the models approach. Member countries will be free to opt for earlier implementation. As a general principle, banks which start to use models for one

or more risk factor categories will, over time, be expected to extend models to all their market risks, but no time limit will be set, initially at least, for banks which use a combination of internal models and the standardised methodology.

8. The first section of this paper describes the general approach to managing market risks that is common to many large banks using proprietary models. Section II summarises the lessons learned from the testing exercise conducted in 1994. Section III presents certain generalised elements of a proposed supervisory framework for basing market risk capital requirements on banks' internal measurement systems. Section IV discusses quantitative standards for models and Section V looks at stress testing procedures. Section VI describes how examiners and auditors should validate internal models used to calculate supervisory capital charges.

I. Common elements of banks' approaches to risk measurement

1. The internal models methodology for measuring exposure to market risks is based on the following general conceptual framework. Price and position data arising from the bank's trading activities, together with certain measurement parameters, are entered into a computer model that generates a measure of the bank's market risk exposure, typically expressed in terms of ***value-at-risk***. This measure represents an estimate of the likely maximum amount that could be lost on a bank's portfolio with a certain degree of statistical confidence.

2. The remainder of this section describes the main components of this sequential process as it is typically deployed and serves as background for the discussion of the proposed supervisory framework in the subsequent sections of the paper.[3]

(a) Inputs

3. The inputs of the measurement system include the following components:

- ***Position data***, comprising positions arising out of trading activities;
- ***Price data on the risk factors*** that affect the value of the different positions in the portfolio. The risk factors are generally divided into broad categories that include interest rates, exchange rates, equity prices, and commodity prices, with related options volatilities being included in each risk factor category;
- ***Measurement parameters***, which include the holding period over which the value of the positions can change; the historical time horizon over which risk factor prices are observed (observation period); and a confidence interval for the level of protection judged to be prudent. These measurement parameters are in part judgmental; for example, they may depend on the level of protection that the model seeks to provide, unlike the position and price data which are in principle exogenous.

(b) The modelling process

4. Based on the above inputs, an internal valuation model calculates the potential change in the value of each position resulting from specified movements in the relevant underlying risk factors. The changes in value are then aggregated, taking account of historical correlation between the different risk factors to varying degrees - either at the level of an individual portfolio or across trading activities throughout the bank. The movements in risk factors and the historical correlations between them are measured over the observation period chosen by the bank as appropriate for capturing market conditions within its overall strategy.

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[3] The description in this section is for illustrative purposes and is not intended to define an internal model that is approved for supervisory purposes.

5. Banks generally use one of two broad methodologies for measuring market risk exposure: variance/covariance matrix methodology and historical simulation. In the case of the variance/covariance methodology, the change in value of the portfolio is calculated by combining the risk factor sensitivities of the individual positions - derived from valuation models - with a variance/covariance matrix based on risk factor volatilities and correlations. The volatilities and correlations of the risk factors are calculated by each bank on the basis of the holding period and the observation period. The confidence level is then used to determine value-at-risk.

6. The historical simulation approach calculates the hypothetical change in value of the current portfolio in the light of actual historical movements in risk factors. This calculation is carried out for each of the defined holding periods over a given historical measurement horizon to arrive at a range of simulated profits and losses. The confidence level is used to determine the value-at-risk.

7. There is also a third, less widely used approach, the Monte Carlo simulation method, which tests the value of the portfolio under a large sample of randomly chosen combinations of price scenarios, whose probabilities are based on historical experience. This method is particularly useful in measuring the risk in options and other instruments with non-linear price characteristics but is less frequently used to measure the market risk in a broad portfolio of products.

(c) Output

8. Each of the measurement methods described produces a final value-at-risk number. Depending on the way the model is constructed, this number may be calculated for individual positions, for different risk factor categories or for exposure to all kinds of market risk. The numbers generated serve as the basis for monitoring exposure levels and exposure limits and at some banks for allocating capital internally across the different business lines of the bank.

II. Lessons learnt from the testing exercise

1. In order to help determine which model parameters should be standardised or constrained for the purpose of measuring market risk capital requirements, the Committee carried out some preliminary testing in the second half of 1994. One object of the test was to establish how great a difference there would be between different models' measures of value-at-risk when an absolute minimum number of parameters was specified. Another was to check whether the value-at-risk measures would produce, in the Committee's view, reasonable value-at-risk estimates relative to the size of the portfolio. For this purpose, a task force set up by the Committee compiled a test portfolio of approximately 350 positions. The portfolio was evaluated by fifteen banks in the major G-10 countries who measured the value-at-risk produced by their own models for the portfolio, using a ten-day holding period and a 99% confidence interval, as of the same date. In doing so, they were asked to produce a total value-at-risk figure, as well as individual values-at-risk for foreign exchange, interest rate and equity risk categories and also to test four different variants of the portfolio, one balanced and one unbalanced, each with and without options positions.

2. Although the raw results provided by the banks were quite disparate, further investigation was able to pinpoint the main factors contributing to the observed differences. Among the several factors which led to the dispersion, the easiest ones to interpret related to ambiguities which occurred in inputting the portfolio and the fact that banks were using methods of varied sophistication for measuring options risks. After accounting for these factors, slightly over half of the individual responses fell into a sufficiently close range but significant overall dispersion remained.

3. The exercise identified several important differences in model practice that appeared to be responsible for differences in the test results. Although the Committee realises the inherent limitations of a single testing exercise, it believes that the main systematic differences in model output are related to the following factors:

- when inviting banks to conduct the testing the Committee's task force did not set any constraints on the *historical time horizon* over which price volatility is observed. Some of the participating banks use very short periods, as short as a few months, while others use periods of several years;
- another cause of dispersion in the overall value-at-risk measures was *differences in the methods of aggregating different measures of risks*, both within and across risk factor categories (e.g. exchange rates, interest rates). For example, some banks aggregated their value-at-risk numbers for different risk factor categories using a simple sum method, others used a "square root of the sum of the squares" method, whereas others used historical correlations;
- *treatment of options risk* varies across banks, as many are still researching and implementing more advanced approaches;

- yet another difference in the measure of interest rate risk was caused by the *number and definition of interest rate risk factors* used by different banks. For example, the number of time buckets used varied widely and banks had different ways of measuring the risk of changes in the yield curve and spreads between yield curves;
- so far as the basic methodology for calculating value-at-risk is concerned, the task force found no systematic difference between the results of banks using the historical simulation approach and the variance/co-variance approach.

4. In summary, the preliminary testing exercise was extremely useful in providing further insight into the issues which arose from the use of internal models. The Committee has been guided by these insights in its choice of quantitative and qualitative standards set out in the remainder of this paper.

III. General elements of a supervisory framework for the use of internal models in the measurement of market risks

1. The results of the testing have confirmed the Committee's view that the type of methodology described in Section I could be considered as a basis for setting regulatory capital charges, subject to a number of quantitative and more generalised conditions which banks would have to observe if they are to be allowed to use in-house models for this purpose. The guiding principle of such an approach is the preservation of banks' incentives to measure market risks as accurately as possible and to continue to upgrade their internal models as financial markets and technology evolve. It is important to ensure, in particular, that the use of models as a basis for measuring capital requirements does not introduce a bias in favour of less rigorous assumptions in terms of measurement parameters. This section describes a number of more generalised criteria which banks using models will be expected to observe in calculating value-at-risk for capital purposes (this does not mean that they have to use the same parameters for measuring value-at-risk for internal risk management purposes). The following sections discuss the use of more specific criteria for the use of internal models in the measurement of market risk capital requirements.

(a) Qualitative standards

2. When evaluating a bank's market risk measurement system, the first priority for supervisory authorities is to assure themselves that the system is conceptually sound and implemented with integrity. **Consequently, supervisory authorities will specify a number of qualitative criteria that banks using a models-based approach must meet. These criteria are set out in Part B of the Supplement**. In most cases, the qualitative standards are self-explanatory. However, one requirement, so-called stress testing, is addressed in Section V below.

(b) Specification of market risk factors

3. The risk factors contained in a bank's market risk measurement systems should be sufficiently comprehensive to capture all of the material risks inherent in the portfolio of its on- and off-balance-sheet trading positions. The risk factors should cover interest rates, exchange rates, equity prices, commodity prices, and volatilities related to options positions. Although banks will have some discretion in specifying the risk factors for their internal models, the Committee believes that they should be subject to the series of guidelines set out in Part B of the Supplement.

4. Overall, these guidelines tend to be of a general character to allow for a number of possible approaches to measuring market risk. However, a common theme that runs throughout the proposed standard is that the level of sophistication of the risk factors used should be commensurate with the nature and scope of the risks taken. **For example, in measuring exposure to interest rates, the Committee has concluded that a minimum of 6**

maturity bands (each representing a separate risk factor) needs to be used for material positions in the various currencies and markets. However, institutions that hold a large number of positions of different maturities or that engage in complex arbitrage strategies require a greater number of risk factors to measure their exposure to interest rates effectively. In addition, all banks using the internal models approach should be in a position to measure spread risk (e.g. between bonds and swaps), with the sophistication of approach again being a function of the nature and scope of the bank's exposure to interest rates. In the case of options, where the risks are particularly complex, the specific conditions set out in Section IV(e) would apply.

(c) Specific risk for models

5. The methodology for banks not using internal models is based on a "building-block" approach in which the specific risk and the general market risk arising from securities positions are measured separately. The focus of many internal models is on bank's general market risk exposure, leaving specific risk (i.e. exposures to specific issuers) to be measured largely through separate credit risk measurement systems. However, this is not universally the case. Moreover, the extent to which specific risk is captured for one risk factor may differ from the extent to which it is captured for another risk factor, even within the same bank. As is stated in paragraph 11 of Section I of the accompanying Supplement, the Committee believes that a separate capital charge should apply to the extent that the model does not capture specific risk. However, for banks using models, the total specific risk charge applied to debt securities *or* to equities should in no case be less than half the specific risk charges calculated according to the standardised methodology. Banks are invited to express their views on how to calculate the extent to which a model is measuring specific risk in order to avoid possible double-counting.

IV. Quantitative standards

1. To address supervisors' prudential concerns and in order to ensure that the dispersion between the results of different models for a uniform set of positions are confined to a relatively narrow range, banks which use models as a basis for calculating market risk capital will be subject to a number of parameters governing the way in which models are specified. The way in which these parameters are selected and the manner in which the capital charge is to be calculated are discussed in this section.

(a) The *holding period* for calculating potential changes in the value of the bank's trading portfolio

2. In selecting a holding period over which price changes are measured, a number of considerations need to be balanced. Save in exceptional circumstances, the longer the holding period the greater is the expected price change and consequently the measured risk. Many banks' models used for trading purposes currently employ a one-day holding period for the measurement of potential changes in position values. This approach is not unreasonable in the context of a trading environment under normal market conditions, where trading managers can take day-to-day decisions to adjust risk. For capital purposes, however, it seems prudent to consider potential changes in value over somewhat longer horizons. In large measure, the use of a longer holding period reflects the possibility that markets may become illiquid, preventing market participants from being able to trade out of losing positions quickly. In addition, a longer holding period will take greater account of instruments with non-linear price behaviour, such as options. At the same time, the holding period should not be so long as to be unrealistic in the light of banks' past experience in winding down positions.

3. The market risk proposal of April 1993 envisaged a holding period of at least two weeks in order to guard against the consequences of banks being locked into unprofitable positions. The Committee continues to believe that a two-week holding period is necessary for the reasons explained above. **Thus the Committee has concluded that the holding period used to measure value-at-risk for market risk capital purposes should be two weeks (ten business days), taking the bank's trading positions as fixed for this interval.** In computational terms, the intention is to hold the bank's trading positions fixed and to apply changes in risk factors that are based on movements over ten-day intervals. Nonetheless, except for their options positions, banks would be free to continue to use risk factor changes based on shorter holding periods, as long as the resulting figures are scaled up to a ten-day holding period. For example, the value-at-risk calculated according to a one-day holding period could be scaled-up by the "square root of time" method by multiplying by 3.16 (the square root of ten trading days). However, this extension is not suitable for options for the reasons explained in sub-section (e) below.

(b) The *observation period* over which historical changes in prices are monitored and their volatilities and correlations measured

4. The historical sample period (or "time horizon") over which past changes in prices are observed varies among banks according to each bank's general strategy. A bank which wants its model to be responsive to short-term market trends and volatilities may apply a relatively short horizon. Banks wishing to evaluate their risk in the light of a medium-term evolution of volatility may look back over a historical period of several years. The question of data availability is also relevant since for many instruments with relatively short lives, lengthy historical data are non-existent and proxies must be used.

5. At any given point in time the choice of historical sample period can have a significant impact on the size of the estimated value-at-risk produced by an internal model. Short sample periods are more sensitive to recent events than long sample periods but this very sensitivity means that for a fixed set of positions a short sample period leads to greater variability in the measure of value-at-risk relative to a longer measurement horizon. Although a longer time horizon may sound more conservative, the value-at-risk depends on how rapidly prices have changed in different time periods. If recent price volatility has been high, a measure based on a short horizon could lead to a higher risk measure than a horizon covering a longer but overall less volatile period. The disadvantage of a short time horizon is that it captures only recent "shocks", and it could lead to a very low measure of risk if it coincides with an unusually long stable period in the markets. The disadvantage of a longer time horizon is that it does not respond rapidly to changes in market conditions: in this case, the value-at-risk will react only gradually to periods of high volatility, and the reaction may be small if the period of high volatility is relatively brief.

6. Recognising that different time horizons may legitimately reflect individual banks' assessments of how best to measure their risk under current conditions, the Committee does not feel it would be desirable to impose a fixed historical sample period for all institutions that use the internal models approach. On the other hand, the testing exercise conducted in 1994 indicated that the use of widely different time horizons contributes importantly to the variability in measured value-at-risk that may occur for a given set of positions across banks. **The Committee has concluded that a constraint should be set on banks' choice of time horizon.** Accordingly, banks will at the least be required to apply a minimum historical sample period of one year for calculating value-at-risk (with freedom to opt for longer periods if they so wish). The Committee is also reviewing the possibility of requiring banks to calculate value-at-risk according to the higher of two value-at-risk numbers obtained by using two historical sample periods to be determined individually by each bank, one long-term (at least one year) and one short-term (less than one year, with, for example, a difference of at least six months between them). Using a "dual" sample period of this kind would on average introduce an additional layer of conservatism in banks' value-at-risk estimates by capturing

short-term volatility, albeit at the cost of a greater processing burden. Comment is invited on the validity and technical feasibility of these two alternatives.

7. The Committee is also aware of the existence of methods that do not weight all past observations equally. While such methods do not initially seem to fit easily within the proposed scheme, the Committee is confident that a way can be found to incorporate such schemes (possibly with modification) into the spirit of the proposed limitation. Comment is specifically invited on possible approaches to this issue.

8. Dispersion of results can also arise from banks' choice of historical data used to observe past price movements. The Committee doubts whether it is practical to seek to steer banks toward uniform data sets, but the data clearly need to be subject to a strong control process. In this context, it is essential that the data be updated and the correlations and volatilities recalculated at frequent intervals. The Committee has decided to set a maximum interval of three months for such recalculation, but banks should also reassess their data sets whenever market conditions are subject to material changes.

(c) The supervisory *confidence level* for potential value-at-risk loss amounts

9. In specifying a value-at-risk model, one of the variables that has to be determined is the level of protection judged to be prudent. The confidence intervals used by banks typically range from 90% to 99%. As a prudential matter, the Committee feels it is appropriate to specify a common and relatively conservative confidence level. **It is therefore specifying that all banks using the models approach employ a 99% one-tailed confidence interval**. A confidence level of 99% means that there is a 1% probability based on historical experience that the combination of positions in a bank's portfolio would result in a loss higher than the measured value-at-risk.

(d) Limits on *aggregation* methods

10. In measuring the risk in a portfolio, it is a standard statistical technique to take account of the fact that the price movements of certain instruments (e.g. debt securities with similar coupons or closely-correlated currency pairs) tend to move together. However, observed correlation among some instruments (e.g. foreign exchange rates and equities), while at times perhaps significant, may be unstable; in unusual market conditions, some of the assumed correlations may break down, occasioning losses that greatly exceed measured risk. The Committee has therefore given careful consideration to the possibility of disallowing certain correlations for the purposes of calculating regulatory capital.

11. This is a complex issue because it is difficult to determine in advance which correlation assumptions are or are not prudent. One correlation assumption is not always more conservative than another. For example, an assumption of independence (i.e. zero

correlation)[4] between interest rates and equity prices may not be conservative if a bank holds long positions in both equities and bonds. In practice, most models calculate the correlations within risk factor categories but differ in their treatment of correlations across broad groups of risk factors.

12. The Committee believes that attempts to stipulate detailed and specific correlation assumptions would be difficult and, for certain portfolio compositions, could lead to an underestimation of risk. However, the disadvantage of relying solely on past historical relationships to determine prudential capital standards is also recognised. Of particular concern is the reliance on historical correlations across broad risk factor categories where the interrelationships of market factors may be more tenuous. Given its desire to reduce the potential for dispersion and to address the prudential concerns addressed above, the Committee favours an approach which gives banks flexibility on the use of correlation assumptions but limits correlations across risk factor categories:

- **within each risk factor category (e.g. interest rates, foreign exchange rates, equity prices and commodity prices, including related options volatilities in each risk factor category), a bank would have the flexibility to use correlations it deems appropriate, provided that its supervisor is satisfied that the process for calculating correlations is carried out with integrity**;[5]
- **across risk factor categories, value-at-risk numbers should be aggregated on a simple sum basis**.

13. The Committee recognises that this treatment is conservative in that it assumes that the "worst case" outcomes for each risk factor category occur simultaneously. However, of the fifteen major market banks which participated in the 1994 testing exercise, more than half used a simple sum approach to aggregate value-at-risk across risk factors, while the others used either a root-sum-of-squares method or empirical correlations. Clearly, therefore, a common industry practice for the treatment of correlations across risk factor categories has yet to emerge. The simple sum approach is preferred by the Committee to other alternatives (such as the root sum of squares approach) because it does not incorporate correlation assumptions that might prove lenient in the event of severe or prolonged market movements.

(e) Accurate measurement of *options* and other instruments that display option-like behaviour

14. Currently, there are differences in the degree to which banks are able to incorporate options risk into their market risk models. Some banks rely on approximations of

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4 This is done by using the "square root of the sum of the squares" method to aggregate across risk factor groups.

5 However, as explained in Section V, banks' stress testing ought to include the effect of a breakdown of historical correlations within risk factors as part of its on-going risk management process.

options price movements, which may fail to take account of the fact that options are non-linear, i.e. their prices do not move proportionately with the price of the underlying. However, a number of large banks are moving towards more sophisticated simulation techniques that would more fully account for non-linear price behaviour. In order to encourage a movement over time to more sophisticated risk measurement techniques, it is important to establish requirements concerning the treatment of options that provide strong incentives for banks to update and to refine their risk measurement systems in this area.

15. Against this background, the Committee has come to the conclusion that banks' internal risk measurement systems should capture the non-linear behaviour of options prices with respect to changes in underlying rates or prices. At a minimum, banks' internal risk measurement systems should incorporate option price behaviour through a non-linear approximation approach involving higher-order risk factor sensitivities (such as gamma). The direct use of options risk management models to calculate all possible changes in option values - which would more fully capture the non-linearity inherent in options positions, at a somewhat higher computational cost - should be considered as a longer term goal for banks' market risk systems.

16. It is also important that banks calculate changes in option values based on movements in underlying risk factors measured on relatively long holding periods, because "scaling up" the value-at-risk figures generated by a one-day holding period assumption would fail to capture non-linearity, which is more pronounced for larger changes in underlying risk factors. The two-week holding period suggested in (a) above seems to be adequate for this purpose. This means that banks would *not* be permitted to scale up by the square root of time their value-at-risk for options positions.

17. In contrast to most other instruments, options values are affected by the volatility of the underlying rates and prices as well as by changes in the level of these factors. As a result, banks' risk measurements systems should evaluate the impact of changes in volatility on option values (vega). In practice, this can be accomplished by modelling volatilities as additional risk factors and including them in the overall set of risk factors affecting the value of the bank's trading positions. Banks with relatively large or complex options portfolios should also measure volatilities across different points along the yield curve.

(f) Calculation of the capital charge

18. The Committee has examined carefully how banks' value-at-risk measures based on the parameters described above can be converted into a capital requirement that appropriately reflects the prudential concerns of supervisors. One of the problems of recognising banks' value-at-risk measures as an appropriate capital charge is that the assessments are based on historical data and that, even under a 99% confidence interval, extreme market conditions are excluded. The Committee does not believe that a ten-day

value-at-risk measure provides sufficient comfort for the measurement of capital for a number of reasons, which include:

- the past is not always a good guide to the future;
- the assumptions about statistical "normality" built into some models may not be justified, i.e. there may be "fat tails" in the distribution curve;
- the correlations assumed in the model may prove to be incorrect;
- market liquidity may become inadequate to close out positions.

19. Many of the factors listed above are very difficult to quantify. Even if they were capable of quantification, a judgement would still have to be made as to how far it is necessary to guard against rare market occurrences. **The conclusion of the Committee is that supervisors would not have sufficient comfort unless the value-at-risk measure, calculated according to the quantitative standards set out in this section, were to be multiplied by an appropriate factor.** Such a multiplication factor would provide a means of adjusting the value-at-risk numbers (using the parameters set out earlier) generated by banks' internal models to produce an enhanced level of capital coverage against losses that banks might sustain in the event of severe or prolonged market movements. The Committee, however, emphasises that the multiplication factor is *not* meant to substitute for regular stress testing (see Section V below) by market participants themselves.

20. The *multiplication factor* will be set by individual supervisors on the basis of their assessment of the quality of the bank's risk management system, subject to an absolute minimum of 3 (although this minimum number may be reviewed in light of additional experience). **The Committee has agreed that banks should be required to add to this factor a "plus" directly related to the ex-post performance of the model, thereby introducing a built-in positive incentive to keep high the predictive quality of the model** (e.g. it could be derived from the outcome of so-called "back-testing" and be zero when such results are satisfactory). More work will be done during, and on the basis of, the consultation to check further the feasibility of the "plus" and to arrive at a more precise definition of it.

21. The question of the appropriate capital charge is also related to the accepted rule that banks' capital requirements should be met on a continuous basis. One of the characteristics of market risk is that it is far more volatile than credit risk. The value-at-risk measure produced by a model will change not only when the bank's positions move, but also when the market moves sharply (especially the risk in the options book). **The Committee recommends that banks should be required to meet, on a daily basis, a capital requirement expressed as the *higher* of :**

- **the previous day's value-at-risk number calculated according to the parameters established in sections (a) to (e) above;**

- **an average of the value-at-risk measures on each of the last sixty business days, multiplied by the multiplication factor designated by the national supervisor.**

22. Basing the capital requirement on the higher of these two measures has the advantage of placing a lower limit on the capital requirement. When the bank's value-at-risk measure, which can fluctuate on a day-to-day basis, produces a relatively low number on a given day, the sixty-day average multiplied by the multiplication factor effectively becomes the capital requirement, thus imposing a certain level of stability and providing a cushion for potential losses that could arise during periods of greater stress. At the same time, banks must also maintain on a continuous basis a sufficient level of capital to guard against peak levels of value-at-risk, as measured by the previous day's value-at-risk number calculated according to the quantitative standards set out in Part B of the Supplement. Banks therefore also need to evaluate whether the sixty-day average scaled up by the multiplication factor produces a sufficient capital cushion for such potential upsurges in measured value-at-risk over short periods of time.

23. Basing the use of internal models on a series of rigorous qualitative standards and ensuring that these are upheld on a continuous basis through the external validation process should give supervisors comfort about the accuracy of banks' internal models, including the principle that banks conduct back-testing. This is done by comparing ex post the risk measure generated by their internal models against actual daily profits and losses over longer periods of time, as well as looking at hypothetical profits and losses generated by the (end-of-day) portfolio used for the value-at-risk calculation. If supervisors fail to gain sufficient comfort, they may either wish to demand that the model specifications be tightened or may increase the bank's multiplication factor (or, in an extreme case, disallow the model altogether). The supervisors might also wish to compare the results of stress tests with the level of capital produced under the requirements laid down. In any event, they will have a number of means of checking that a bank's model is providing an accurate measure of risk.

V. Stress testing

1. Banks that use the internal models approach for meeting market risk capital requirements must have in place a rigorous and comprehensive stress testing program. Stress testing to identify events or influences that could greatly impact banks are a key component of a bank's assessment of its capital position.

2. Understanding and protecting against the vulnerabilities of a financial company's risk-taking activities is of course one of the major responsibilities of its board of directors and senior management. Banks' stress scenarios need to cover a range of factors that can create extraordinary losses or gains in trading portfolios, or make the control of risk in those portfolios very difficult. These factors include low-probability events in all major types of risks, including the various components of market, credit, and operational risks. Stress scenarios need to shed light on the impact of such events on positions that display both linear and non-linear price characteristics (i.e. options and instruments that have options-like characteristics).

3. Banks' stress tests should be both of a quantitative and qualitative nature. Quantitative criteria should identify plausible stress scenarios to which banks could be exposed. Qualitative criteria should emphasise that two major goals of stress testing are to evaluate the capacity of the bank's capital to absorb potential large losses and to identify steps the bank can take to reduce its risk and conserve capital. This assessment is integral to setting and evaluating the bank's management strategy and the results of stress testing should be routinely communicated to senior management and, periodically, to the bank's board of directors.

4. The Committee recognises the difficulty associated with identifying standardised stress scenarios that will have a consistent impact across all banks. In general, the impact of any given set of market movements will depend crucially on the particular positions held in a bank's trading portfolio. In this regard, the Committee has carefully considered the trade-offs between standardisation of the stress scenarios that banks would be required to evaluate and the difficulties of permitting some degree of bank-specific analysis while ensuring a common degree of rigor. The Committee concludes that the best way to address these difficulties is to combine the use of supervisory stress scenarios with stress tests developed by individual banks to reflect their specific risk characteristics. Specifically, supervisors may ask banks to provide information on stress testing in three broad areas, which are discussed in turn below.

(a) Supervisory scenarios requiring no simulations by the bank

5. Banks should have information on the largest losses experienced during the reporting period available for supervisory review. This loss information could be compared to the level of capital that results from a bank's internal measurement system. For example, it could provide supervisors with a picture of how many days of peak day losses would have been covered by a given value-at-risk estimate.

(b) Scenarios requiring a simulation by the bank

6. Banks should subject their portfolios to a series of simulated stress scenarios and provide supervisors with the results. These scenarios could include testing the current portfolio against past periods of significant disturbance, for example the 1987 equity crash, the ERM crisis of 1993 or the fall in bond markets in the first quarter of 1994, incorporating both the large price movements and the sharp reduction in liquidity associated with these events. A second type of scenario would evaluate the sensitivity of the bank's market risk exposure to changes in the assumptions about volatilities and correlations. Applying this test would require an evaluation of the historical range of variation for volatilities and correlations and evaluation of the bank's current positions against the extreme values of the historical range. Due consideration should be given to the sharp variation that at times has occurred in a matter of days in periods of significant market disturbance. The 1987 equity crash, the suspension of the ERM, or the fall in bond markets in the first quarter of 1994, for example, all involved correlations within risk factors approaching the extreme values of 1 or -1 for several days at the height of the disturbance.

(c) Scenarios developed by the bank itself to capture the specific characteristics of its portfolio.

7. In addition to the scenarios prescribed by supervisors under (a) and (b) above, a bank should also develop its own stress tests which it identifies as most adverse based on the characteristics of its portfolio (e.g. problems in a key region of the world combined with a sharp move in oil prices). Banks should provide supervisors with a description of the methodology used to identify and carry out the scenarios as well as with a description of the results derived from these scenarios.

8. Stress testing alone is of limited value unless the bank is ready to respond to its results. At a minimum, the results should be reviewed periodically by senior management and should be reflected in the policies and limits set by management and the board of directors. Moreover, if the testing reveals particular vulnerability to a given set of circumstances, **the national supervisors would expect the bank to take prompt steps to manage those risks appropriately (e.g. by hedging against that outcome or reducing the size of its exposures).**

VI. External validation

1. An independent review and validation of banks' market risk measurement systems is essential if supervisors are to be assured that banks' measurement systems not only meet the standards described above but also that the models are well designed and implemented with integrity. The main focus of this review should be on the adequacy of the internal validation process and of the documentation of the bank's policy and procedures. The generalised components of an adequate validation process are set out in the accompanying Supplement.

2. The Committee has considered a number of ways of enhancing the ability to validate the output of banks' internal risk measurement models. This discussion has focused on determining what sort of information would be useful (a) in understanding the factors determining a bank's estimate of its market risk exposure and (b) in gaining comfort that the estimates are a reasonable representation of the actual risks arising from the banks' trading activities.

3. The Committee is also considering to conduct occasional further tests of the type conducted in the second half of 1994 and planned for the consultative period. Such exercises produce extremely useful comparative information about the results of banks' risk measurement models, although it is recognised that they require time, expertise and resources on the part of contributing banks. Nevertheless, it is inevitable that supervisors should wish to satisfy themselves that banks' models produce reasonably consistent results.

4. The Committee believes it essential that banks conduct back-testing (see paragraph IV.23), and that they make the results and the underlying inputs to the value-at-risk calculation available to their supervisors and/or external auditors on request. Such comparisons would provide the supervisors with a useful tool for evaluating how accurately banks' internal models are able to measure the market risk of their portfolio over time.

5. The development of rigorous stress tests, as set out in V above, is a key element of a meaningful validation scheme, since it is important to ensure that the capital generated by the market risk capital charge is sufficient to withstand losses that might result from unanticipated market movements (for instance, when correlation assumptions break down). It is a deliberate objective of the Committee to encourage banks to develop stress tests that are tailored to their individual risk profiles.