INTERNATIONAL STANDARD

ISO 8821

First edition
1989-06-01

Mechanical vibration — Balancing — Shaft and fitment key convention

Vibrations mécaniques — Équilibrage — Convention relative aux clavettes d'arbres et aux éléments rapportés

Reference number
ISO 8821 : 1989 (E)

Foreword

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Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council. They are approved in accordance with ISO procedures requiring at least 75 % approval by the member bodies voting.

International Standard ISO 8821 was prepared by Technical Committee ISO/TC 108, *Mechanical vibration and shock.*

Annexes A, B, C, D and E of this International Standard are for information only.

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Printed in Switzerland

Introduction

There are currently three methods or "conventions" for balancing shafts or rotors and their fitments coupled together with keys:

- full-key convention;
- half-key convention;
- no-key convention.

It is often impossible or economically unreasonable to balance rotors and fitments after they have been assembled; they are, therefore, balanced separately. An appropriate balance tolerance is applied to each so that, when rotor and fitment are coupled together with the appropriate key, the assembly will meet the required balance tolerance and vibration severity level. However, if a different key convention has been used when balancing the shaft or rotor than the one used for balancing the fitment, it is quite likely that the assembly will have balancing errors exceeding the permissible residual unbalance.

This International Standard is intended to unify the key conventions used throughout the world. When consistently used, it will result in compatibility of shafts or rotors and fitments so that they can be balanced by different suppliers and, after being assembled, will meet balance and/or vibration tolerance levels for that assembly.

Mechanical vibration — Balancing — Shaft and fitment key convention

1 Scope

1.1 This International Standard specifies a single convention for balancing the individual components (shafts or rotors, and fitments) of a keyed assembly. It is intended to provide compatibility of all balanced components so that when they are assembled they will meet the overall balance and/or vibration tolerance levels for that assembly.

1.2 This International Standard requires that half keys be used when balancing the individual components of a keyed assembly to avoid the balancing errors created if full keys or no keys were used.

1.3 This International Standard applies to rotors balanced in balancing machines, in their own housings, or *in situ*. This key convention should also be applied when measuring residual unbalance and vibration severity of rotors utilizing keyways but to which the fitments have not yet been assembled.

1.4 Although the figures in this International Standard show keys of constant rectangular or square cross-section, mounted parallel to the shaft axis, this International Standard applies also to keys mounted on tapered shaft surfaces, to woodruff, gib, dowel and other special keys. The principle of the half-key convention as outlined in the definition and elsewhere is then applied as is appropriate to the particular shape and location of the special key.

1.5 This International Standard includes instructions for the implementation (see annex A) and for the transition period that will occur as the half-key convention is adopted (see annex B).

2 Normative reference

The following standard contains provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the edition indicated was valid. All standards are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent edition of the standard listed below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 1925 : 1981, *Balancing — Vocabulary.*

3 Definitions

For the purposes of this International Standard, the definitions given in ISO 1925, together with the following, apply.

3.1 fitment: Component without its own shaft which has to be mounted on a shaft or mandrel before its unbalance can be determined.

Examples include couplings, pulleys, pump impellers, blower fans and grinding wheels.

NOTE — A fitment becomes a rotor when it is placed on a shaft with journals (see also the definition of "rotor" in ISO 1925). This could not only be a balancing mandrel but also the shaft extension of an armature, which by itself already is a rotor. To avoid confusion between fitment and rotor, this International Standard hereafter uses only the terms fitment and shaft, whereby the latter may be any kind of shaft, for example a balancing mandrel, an armature shaft, turbine shaft, pump shaft, etc.

3.2 key; full key: Locking device used to prevent rotation between a fitment and its mating component, usually a shaft.

NOTES

1 Since the full key is used in the final assembly, it is often also called the final assembly key.

2 Figure 1 shows various types of key and keyway configurations.

3.3 half key: Key used in balancing, having the unbalance value of that portion of the final (full) key which will occupy either the shaft keyway or the fitment keyway in the final assembly.

NOTES

1 The unbalance value of the half key for a given shaft may differ from that needed for the mating fitment (of equal keyway length) due to differences in distance from the shaft centreline, depth of keyways, and clearances.

2 The required unbalance value for a half key may be calculated by assuming that the full key is separated into two half keys along the contoured parting line between shaft and fitment, taking half the height clearances of key and keyway in each of the key halves into consider ation (see figure 2).

4 Half-key convention

4.1 Description

The half-key convention requires that a half key be used in the shaft keyway while balancing the shaft without its fitment. A

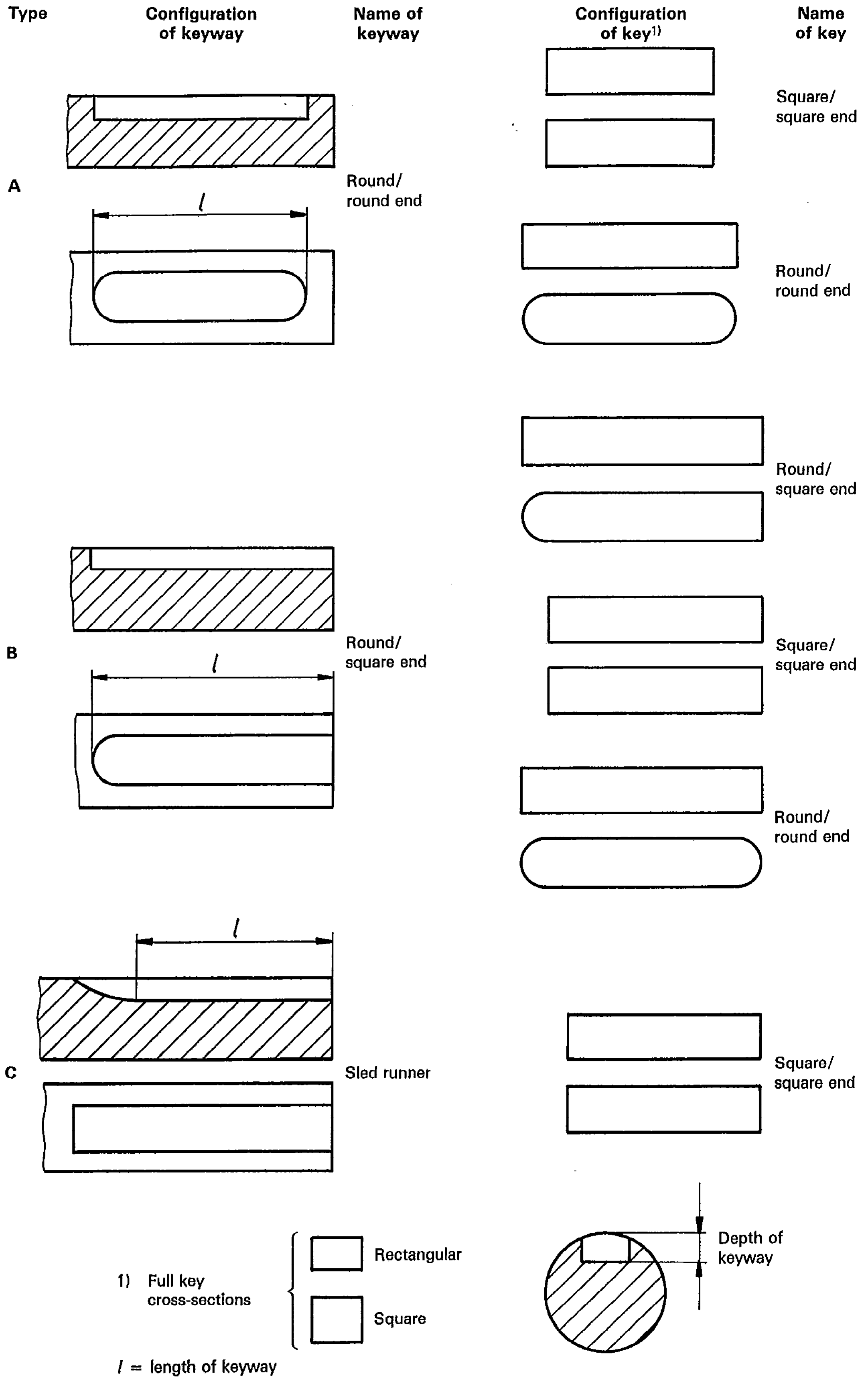


Figure 1 — Major types of shaft keyways and keys (see also ISO/R 773 and ISO/R 775)

complementary half-key is used while balancing the fitment on a balancing mandrel, provided it has no keyways. If the mandrel has keyways, see the alternative methods specified in A.2.2. The axial location of the centre of gravity of the half key should be the same as that of the full key in the final assembly (see figure C.2).

The use of the half-key convention will provide a uniform method for balancing shafts and fitments joined together by keys. It will eliminate balancing errors and therefore excessive residual unbalance (and/or machine vibration) caused by the use of different key conventions, and avoid the creation of internal bending moments in assemblies (as would be caused by the use of full keys during balancing).

4.2 Marking

4.2.1 After balancing, the end of the shaft adjacent to the keyway shall be permanently marked with the letter H to indicate that balancing was performed using the half-key convention. Permanent marking using metal stamps or vibratory engravers is recommended, but a permanent or indelible ink may be used.

If the shaft face is too small for marking, the bottom of the keyway may be used.

4.2.2 After balancing, the face of the fitment adjacent to the keyway shall be *permanently* marked with the letter H to indicate that balancing was performed using the half-key convention. This letter should be readily visible when the fitment is joined to the shaft. Permanent marking using metal stamps or vibratory engravers is recommended, but a permanent or indelible ink may be used.

4.2.3 When balancing a replacement shaft or fitment the known mating part of which has not been balanced using a half key, it is permissible to balance the particular component with the corresponding key convention. In this special case, both components shall be permanently marked with an identification letter corresponding to the key convention used, as follows:

a) components balanced using the full-key convention shall be marked with the letter F adjacent to the keyway;

b) components balanced using the no-key convention shall be marked with the letter N adjacent to the keyway.

4.2.4 The marking of the shaft and the fitment with the letter H may be omitted if confusion as to which key convention was used is unlikely.

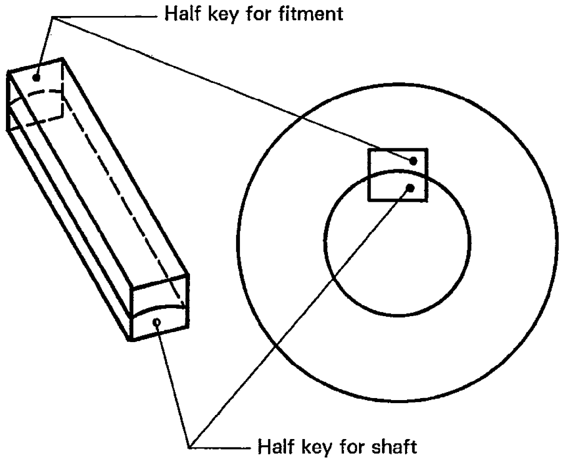


Figure 2 — Contoured half-key set

5 Implementation

All manufacturers of original parts and processed components shall comply with the half-key convention of balancing and mark each newly manufactured rotor and fitment with the letter H.

Change-over of equipment in service to the half-key convention with proper identification of the shaft and fitment during the first repair balancing operation is encouraged; in any case, the marking shall be added.

Annex B gives a transition strategy.

Annex A
(informative)

Recommendations for the implementation of the half-key convention

A.1 Implementation date

To avoid undue confusion between manufacturers and users as to the key convention used, it is recommended that implementation of the half-key convention be accomplished by 1 January 1990.

A.2 Half-key requirements

A.2.1 A half-key is required for the shaft keyway.

A.2.2 For a fitment with a single keyway, one of the following requirements is to be met:

a) when the mandrel has no keyway: use one half key;

b) when the mandrel has two identical keyways 180° opposite each other: use one full key and one half key of equal length;

c) when the mandrel has a single keyway: use one half key (for balancing the mandrel) and one full key (for balancing the mandrel/fitment assembly).

NOTES

1 Mandrel construction using requirement a) or b) are preferred because they are inherently balanced.

2 The balancing mandrel should have the same diametral tolerances as the shaft it is intended to simulate. The mandrel should also have correction planes on it to allow for unbalance correction, index balancing, and biasing.

A.2.3 Special keys such as woodruff, gib or tapered keys require individual consideration.

A.2.4 If a full key is shipped with the shaft, its length is obvious and therefore permits determination of the proper half key for the fitment (see also clause C.4). If no key is shipped with the shaft, the length of the half-key used originally for balancing the shaft is assumed to be the same as the length of the shaft keyway (see also figure 1, dimension l).

A.2.5 Half keys used for balancing should always be made of material having the same specific weight as the final key. Unless specifically stated otherwise, it is to be assumed that final keys are made of steel. Therefore, half keys should also be made of steel.

A.2.6 The half key should be held in place on the shaft by means that introduce negligible unbalance, for example fibreglass tape, but will prevent the half key from accidentally separating from the keyway.

A.3 Exceptions

A.3.1 If a shaft or fitment is provided with two equal keyways 180° opposite each other and two keys are used in the final assembly, it is permissible to balance without keys. This fulfils the requirement of the half-key convention. If the two keyways are not equal or are positioned other than 180° opposite each other, two half keys are required for balancing the shaft and two more for the fitment.

A.3.2 If the vibration tolerance levels of certain assemblies are generous enough to be not exceeded by the change in key convention, or if a manufacturer has a limited number of users who require no shaft repair by or replacement from alternative sources, it may be acceptable to retain a key convention other than the half-key convention; however, all shafts should be marked accordingly.

A.3.3 A half key is not used in certain couplings because they are balanced by the manufacturer without a keyway being machined into the bore. The user of the coupling generally enlarges the bore and machines the keyway to his requirements without rebalancing. This method basically complies with the half-key convention, provided the final key has approximately the same length as the keyway.

A.4 Past key convention practice

After implementation of the half-key convention, there will be in existence for many years shafts and fitments which were manufactured prior to the issue of this International Standard. When such an older (unmarked) shaft or fitment needs to be rebalanced without its mating component being also available for rebalancing, it will be necessary to know to what key convention the other (unavailable) component was balanced. The on-hand component must then be rebalanced to the same convention (and marked), otherwise the rebalancing work will most probably produce unsatisfactory results.

To help determine the key convention to which the other (unavailable) component probably was balanced, table A.1 lists the key conventions used in the ISO Participating and Observer Countries in the past.

Table A.1 — Worldwide past usage of key conventions

Country (Organization)		Shaft key method used
Australia	(SAA)	Not available (N/A)
Austria	(ON)	N/A
Belgium	(IBN)	N/A
Canada	(SCC)	Half key
China	(CSBS)	N/A
Czechoslovakia	(CSN)	Full key
Denmark	(DS)	N/A
Egypt	(EOS)	N/A
France	(AFNOR)	Full key
Germany	(DIN)	Full key since approximately 1965
Hungary	(MSZH)	N/A
Italy	(UNI)	N/A
Japan	(JISC)	Half key
Mexico	(DGN)	N/A
Netherlands	(NNI)	N/A
Romania	(IRS)	N/A
South Africa	(SABS)	N/A
Sweden	(SIS)	Full key on most electrical motors since 1978-01-01. Other rotating machinery indeterminate.
Switzerland	(SNV)	N/A
United Kingdom	(BSI)	Half key prior to 1978-01-01, then full key.
USA	(ANSI)	Half key

NOTES

1 Where no starting date is shown, it is assumed that no convention other than that listed was used previously.

2 Due to European harmonization efforts, it can be assumed that many European countries have used the full-key convention since 1978-01-01.

Annex B
(informative)

Transition to half-key convention

B.1 Manufacturers of shafts and/or fitments coupled together by keys should alert all known holders of inventory of their parts and assemblies of the date on which compliance is to become effective, and suggest the transition strategy to be used until the present inventory is exhausted. Recommended transition procedures are given below.

B.1.1 All shafts and fitments held in stock at a manufacturer, distributor or user which have been balanced in accordance with the half-key convention, are to be marked with the letter H in accordance with 4.2 prior to shipment and/or use. If not so balanced, they are now to be rebalanced to the half-key convention and marked.

B.1.2 Where rebalancing to the half-key convention is not appropriate, all shafts and fitments in stock are to be marked with the applicable convention in accordance with 4.2.

B.2 In the transition period, before the manufacturer has changed over to the half-key convention, the manufacturer may send users new parts or assemblies that are not balanced with the half-key convention. He is to mark these parts with the appropriate identification letter. The user has the option of rebalancing them to the half-key convention but, if he does so, he is then to change the key convention marking.

B.3 A change-over of shafts and fitments in service during the first rebalancing operation is to include the proper marking in accordance with 4.2.

Annex C
(informative)

Practical considerations for making half keys

C.1 Contoured half keys

When the half keys for the shaft and fitment, as shown in figure 2, are put together, they have the same overall dimensions and mass as the full key that will be used in the final shaft/fitment assembly. However, such contoured half keys are rather expensive to manufacture and quite impractical for balancing one-of-a-kind or small lots of shafts or fitments.

C.2 Not-contoured half keys for shafts

Shop practice, therefore, often uses half keys of less than ideal dimensions, such as keys of (approximately) half-height or half-length (see figures C.1 to C.3). The half-length keys are preferable because they are easier to make and provide a closer unbalance value of the idealized contoured half key than the half-height key. In fact, for keys having a square cross-section, a half-length key cut to 48 % of the full mass of the final key will generally have an unbalance value within 2 % of the ideal half key.

If the depth of the keyways differs between shaft and fitment (as for keys with rectangular cross-section described in ISO/R 773 and ISO/R 775), the above rule no longer holds true. Instead, the mass of the half-length key for the shaft should be 45 % of the (final) full key for keys up to 8 mm wide, and 54 % for wider keys. The unbalance values of these half keys will then generally be within 2 % of the ideal value.

The percentages stated above may not be accurate enough to be applicable to half keys used for flexible rotor balancing.

C.3 Not-contoured half keys for fitments

For low volume production, the not-contoured half-height key is prevalent. To compensate for the missing contoured portion facing the shaft, the length of the key should exceed the length of the final (square cross-section) key by 4 %. This is not required for keys complying with ISO/R 773 and ISO/R 775, since there the fitment keyway has sufficient clearance above the key to permit insertion of a half-height key having the same length as the fitment keyway and producing the proper unbalance value.

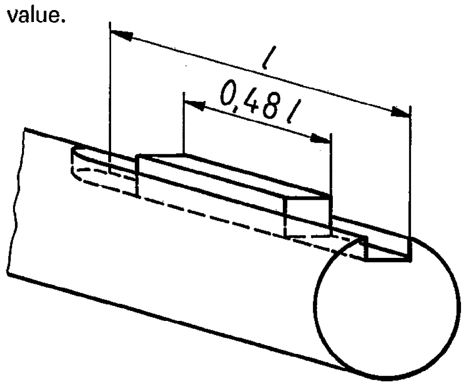


Figure C.2 — Half-length key (for shaft only), its centre of gravity located in the same transverse plane as that of the full key in the final assembly

For high volume production, a half-length key as shown in figure C.3 may be more efficient. The key can be bolted into

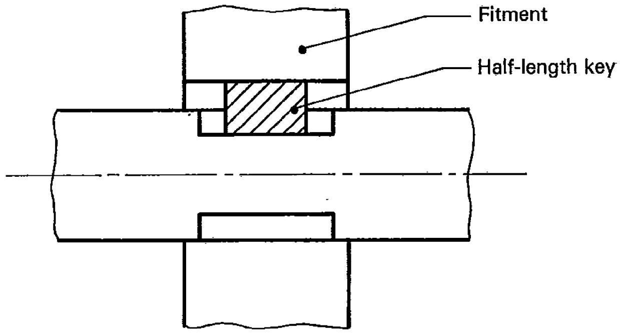


Figure C.3 — Half-length key used for balancing fitment

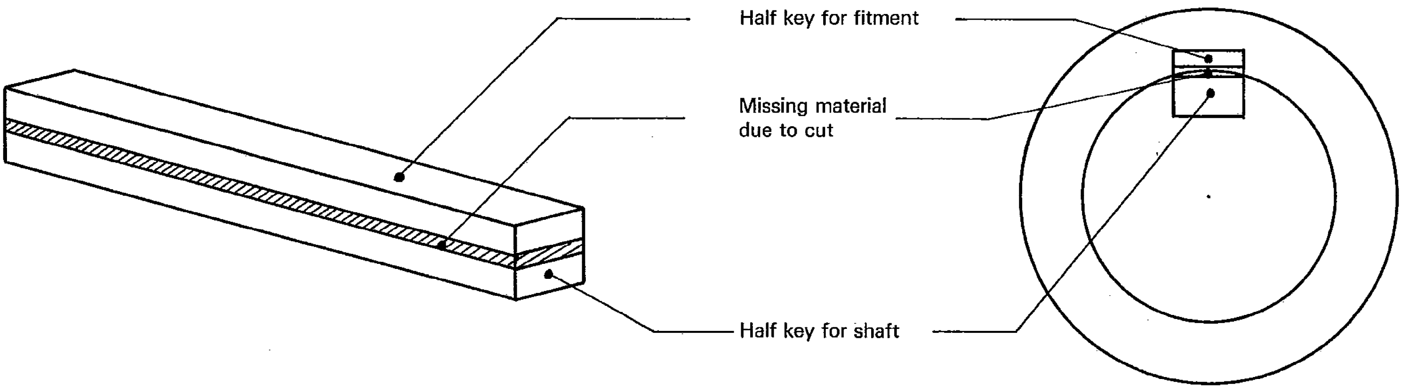


Figure C.1 — Half-height key set

one of the opposing keyways of a balanced mandrel to maintain its axial position. The fitment must be centred over the key during balancing.

C.4 Half-key length

Key lengths are not universally standardized for given shaft diameters. Often shaft and fitment are furnished by different manufacturers, neither knowing the length of the other's keyway. In such cases, the rule is that each manufacturer uses a half key properly dimensioned on the assumption that the final assembly key will occupy the full length of the keyway (see also A.2.4).

Occasionally, an assembler of shaft and fitment will be confronted with a longer keyway in the shaft than in the fitment. To avoid having to rebalance either the shaft with a half key based on the shorter fitment keyway, or the fitment with a half key based on the longer shaft key, one of the following two alternative solutions may be used.

a) Stepped key, machined to have two sections of different height to accommodate different keyway lengths in shaft and fitment (see figure C.4).

b) Average-length key, consisting of a full-height key cut to the average length of the shaft and fitment keyways (see figures C.5 and C.6).

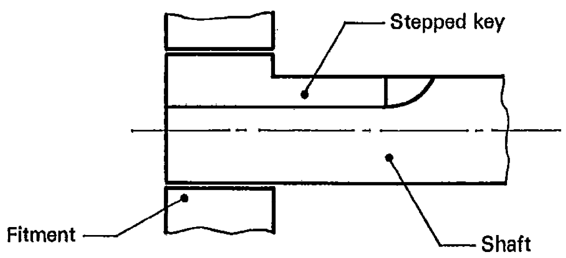
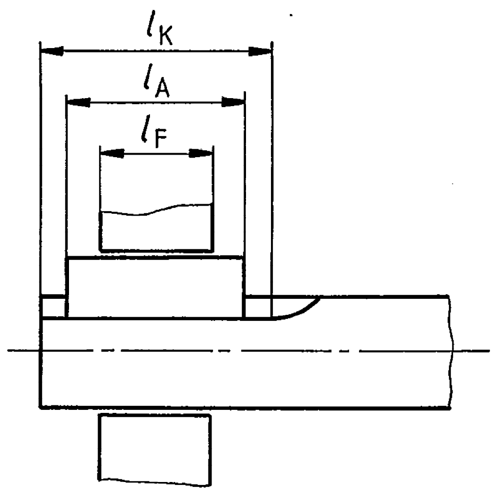


Figure C.4 — Stepped (final) key for short fitment

The ideal axial installation position for the average-length key is in the centre of the rectangular portion of the shaft keyway with the fitment centred on the key (see figure C.5).

Mounting of the fitment in the ideal position, however, is seldom possible. Instead, the fitment is usually installed flush with the shaft end, as shown in figure C.6.

The installation shown in figure C.6 introduces two balancing errors: namely, a couple unbalance because the portion of the key marked "filled" should be in the position marked "not filled", and a quasi-static unbalance because the portion of the key marked "filled" is located at a greater distance from the shaft centreline than the portion marked "not filled" where it should be located. To assess the significance of these errors, they must be transposed into the shaft correction Planes I and II, as shown in figure C.8. In most cases the errors will be negligible.



l_K = length of keyway

l_F = length of fitment

l_A = average length of key

$$l_A = \frac{l_K + l_F}{2}$$

Figure C.5 — Average-length (final) key for short fitment in ideal position

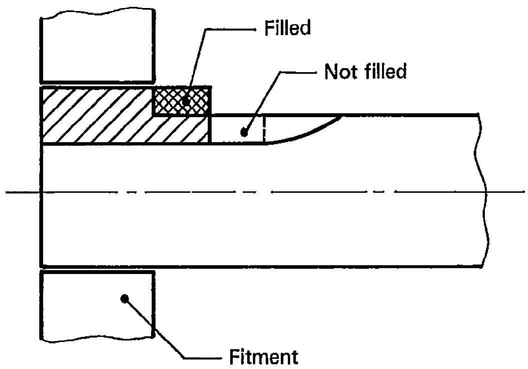


Figure C.6 — Average-length (final) key for short fitment mounted flush with shaft end, producing balancing error

If the fitment keyway is longer than the shaft keyway, the fitment must be balanced with a half-key based on the shorter shaft keyway. Alternatively, a stepped key can be made, the upper half of which fills the full length of the fitment keyway, the lower half filling the shorter length of the shaft keyway.

C.5 Balancing errors due to half keys

Half keys may cause balancing errors (and therefore excessive residual unbalance) because of keyway design clearances, machining tolerances, and deviations from the ideal shape or position. Figure C.7 illustrates some of these errors by showing a cross-section through a shaft and fitment assembly with key and keyway in stationary and then in operational position. Clearances permit the key to tilt slightly. These and other bal-

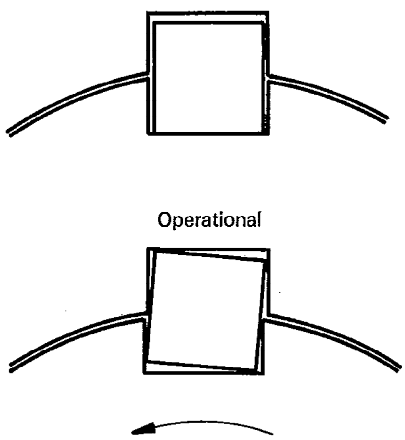


Figure C.7 — Stationary and operational key positions

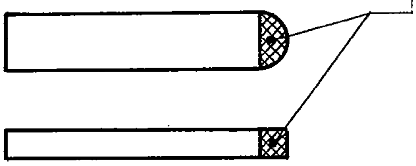


Figure C.9 — Shaft keyway[1] machined with end mill cutter

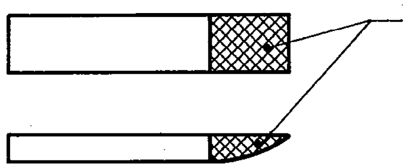


Figure C.10 — Shaft keyway[1] machined with a key slot cutter

ancing errors must be taken into account when setting individual balance tolerances for the shaft and the fitment.

It must be noted that a quasi-static balancing error occurring near the end of a shaft will usually be increased in its effect when translated into the near shaft correction plane. The shaft example in figure C.8 illustrates this point. For Plane I (the near correction plane) the error increases by the ratio x/y, and for Plane II (the far correction plane) it changes by the ratio z/y.

Couple unbalance errors occurring in two closely spaced planes, for example those in figure C.6, usually translate into smaller unbalance values in the shaft correction planes by the ratio of the distances between couple unbalance error planes and shaft correction planes.

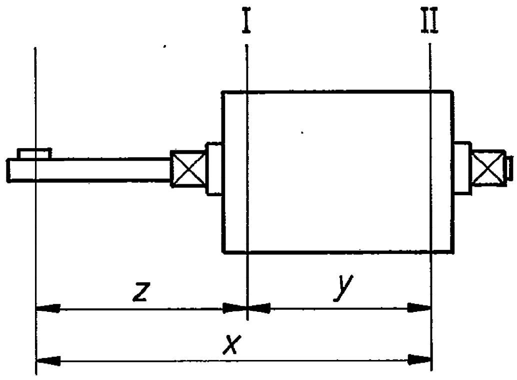


Figure C.8 — Translation of key-caused quasi-static balancing error into shaft (rotor) correction planes

C.6 Shape of keyway end (see figures C.9 and C.10)

Keyways are generally machined into shafts with an end mill cutter (type A and B in figure 1) or with a key slot cutter (type C in figure 1). If the rounded portion of the shaft keyway is not filled by the final key (it *never* is in type C keyways), its unbalance value need not be considered when calculating the size of the half key. Instead, the small void constitutes an unbalance in the shaft and is corrected, together with the other shaft unbalances, in the shaft correction planes. The internal moment thereby introduced into the shaft is of no concern on rigid rotors, but may not be acceptable on flexible rotors.

Fitment keyways are generally machined with a broach or shaper and therefore are rectangular in shape, with both ends open.

If the fitment was balanced with a half key that filled the entire length of the keyway, and is then mounted on a shaft having a key of the same length but with one or two round ends, a small balancing error results. Each round end leaves void two small corner spaces in the fitment keyway. In most cases this error is small enough to be absorbed by the assembly balance tolerance. If not, the error must be corrected by rebalancing the fitment with an appropriately dimensioned half key.

C.7 Use of setscrews

To prevent axial movement of a fitment mounted on a shaft, one or more setscrews are frequently used. These are located in the hub of the fitment directly over the keyway.

When balancing the fitment on a mandrel, it is important that the setscrew(s) be tightened down on the key(s). This will press the mandrel against the fitment bore opposite to the setscrew(s), the same as will be the case in the final assembly of fitment to shaft.

If the fitment has two setscrews offset by 90°, it is important to tighten the setscrews in the same sequence each time. By following these procedures balancing errors are minimized.

1) For identification of shaft keyway types, see figure 1.

Annex D
(informative)

Shaft and fitment key conventions

D.1 Description of methods

There are currently three methods or "key conventions" used for balancing shafts and their fitments:

- full-key convention (see D.1.1);
- half-key convention (see D.1.2);
- no-key convention (see D.1.3).

D.1.1 The full-key convention requires that a full key (usually the final key) be used in the shaft keyway during balancing. No key is used to balance the fitment on a balancing mandrel that has no keyway. If the mandrel has a keyway, it has to be balanced by itself using a full key. That same key is to remain in the mandrel during balancing of the fitment. The location of the full key in the shaft should be in the same axial position that will be used when shaft and fitment are assembled.

D.1.2 The half-key convention requires that a half key be used in the shaft keyway during balancing. A complementary half key is used to balance the fitment on a balancing mandrel that has no keyway. The location of the half key should be in the same axial position that will be used when the shaft and fitment are assembled.

D.1.3 The no-key convention does not use any type of key during balancing of the shaft or its fitment, even though both have keyways.

D.2 Advantages and disadvantages of current conventions

Each of the three balancing conventions has certain advantages and disadvantages associated with it. The most important attributes and drawbacks of each convention are outlined in D.2.1 to D.2.3.

D.2.1 Full-key convention

D.2.1.1 Advantages

The advantages of the full-key convention are that

a) balancing errors from incorrect key mass are avoided by using the final key in the shaft and no key in the fitment;

b) no special half keys need to be manufactured;

c) the keyway in the fitment may be of different length than the shaft key, without affecting the balance of the assembly or requiring a stepped key;

d) the shaft balance (without the fitment) may be checked in the test laboratory or at the job site with the final key;

e) the individual shaft (with full key) and the fitment (without key) both leave the manufacturer's plant in a balanced state.

D.2.1.2 Disadvantages

The disadvantages of the full-key convention are that

a) an additional unbalance in the shaft and in the fitment is produced which results in a correction cost not incurred with the half-key convention. Initial unbalance may exceed allowable or correctable amounts and thus cause shaft rejection;

b) an internal bending moment is produced in the shaft. The projecting part of the key creates an unbalance which has to be compensated by correction masses in at least two planes on the shaft (since it usually cannot be corrected in the plane of the key). The internal bending moment may affect the balance quality of flexible rotors. The internal bending moment will not affect the balance quality of rigid rotors. The internal bending moment remains in the shaft when the fitment is attached (see figure D.1).

c) it creates confusion in world markets because individual manufacturers or countries using this method nevertheless use a half-key method on larger shafts without a consistent or well defined cross-over point. This results in incompatible components if they are supplied by two manufacturers using different key conventions;

d) there is a greater danger of the full key separating from the shaft keyway during balancing since a full key has twice the mass of a half key;

e) it does not allow coupling manufacturers to follow the common practice of balancing their couplings before the keyways are machined.

D.2.2 Half-key convention

D.2.2.1 Advantages

The advantages of the half-key convention are that

a) no unbalance is created in either the shaft or its fitment and therefore no unnecessary unbalance corrections are required;

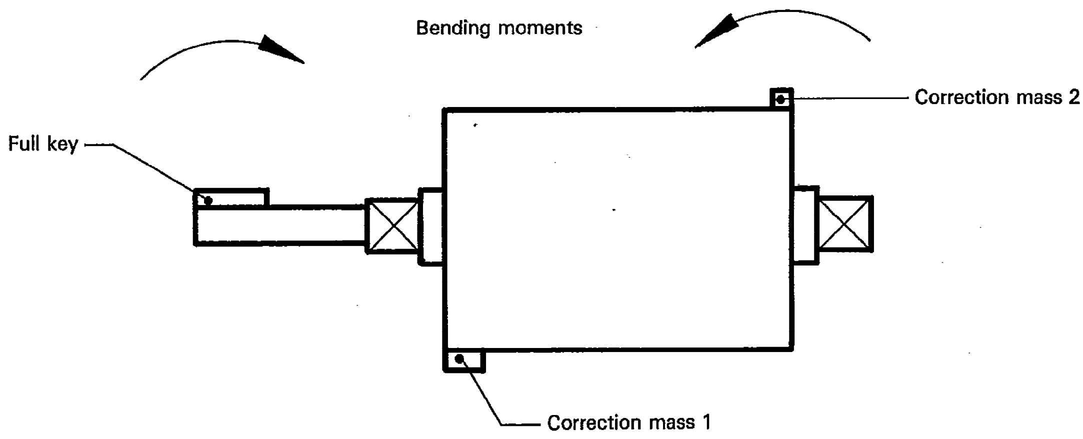


Figure D.1 — Internal moments created when a full key is corrected by two correction masses on the rotor body

b) no internal bending moments are produced in the shaft or fitment;

c) it allows fitments to be balanced before the keyway is machined; this practice is commonly used by coupling manufacturers.

D.2.2.2 Disadvantages

The disadvantages of the half-key convention are that

a) a special key is required for balancing. Balancing errors may be introduced if the half key does not have the proper unbalance value. Special keys, such as woodruff, round and gibhead keys, may be difficult to manufacture;

b) a special key may cause extra expense, particularly in job balancing;

c) a special key is required when assessing the residual unbalance or vibration severity of a shaft without a fitment in the test laboratory or at the job site;

d) if the length of the key used in the final assembly differs from the length of the key used in balancing, an unbalance is produced in the assembly which might cause rejection of the assembly.

D.2.3 No-key convention

D.2.3.1 Advantages

The no-key convention is convenient, since no keys are required either in the shaft or in the fitment.

D.2.3.2 Disadvantages

The disadvantages of the no-key conventions are that

a) the absence of the key produces an unbalance which must be corrected in both the shaft and the fitment during individual balancing;

b) unbalance correction usually cannot be made in the plane of the shaft key; instead, it has to be made in two shaft (rotor) body planes (see also figure D.1). This creates an internal bending moment in the shaft (or rotor) which, in case of a flexible rotor, may affect its balance quality. The internal bending moment will not affect the balance quality of rigid rotors. The internal bending moment remains in the shaft after the fitment has been attached;

c) the addition of the key during assembly of the fitment to the shaft produces an unbalance;

d) it has limited applicability. The method can only be used if permissible residual unbalance for the shaft assembly is larger than the balancing error produced by the missing key. The alternative solution of field balancing after assembly is costly, inconvenient, and sometimes not possible due to inaccessibility of the correction planes.

Annex E
(informative)

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UDC 62-253 : 62-755

Descriptors: rotors, shafts (rotating), balancing.

Price based on 12 pages