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Abstract: Describes a specific structure of an indexed sequential file stored in a backing storage document and a set of RC 4000 Algol standard procedures for processing such a file. 32 pages.

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Introduction

An indexed sequential file is basicly a sequential file, stored on a random access medium, and augmented by one or more levels of index tables to facilitate random access to records specified by a key.

With two levels, buckets and blocks, the search for a record with a specific key proceeds as follows:

A search for the key in the bucket table, which is common for the whole file, will yield a part of the file, the bucket, in which to continue the search.

Each bucket is preceded by a block table and a search in this will yield a part of the bucket, the block, in which the record may be found.

The inherent characteristics for this type of files are:

1. Fast sequential processing of the whole file, comparable to a straightforward sequential file,
2. Fast random access for inspecting and updating of records specified by their keys
3. Fast deletion of records
4. Slow insertion of new records in a file, especially when the file is pretty full.

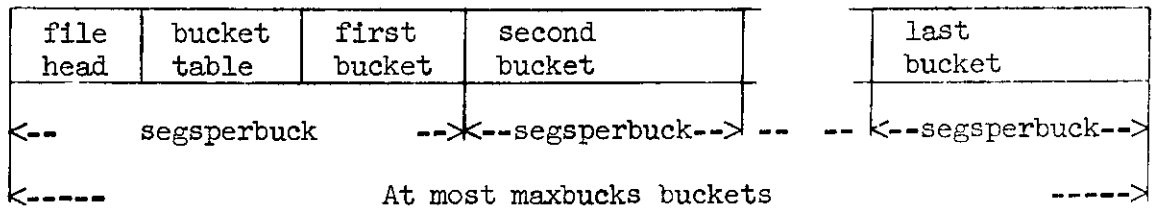
This paper describes the RC 4000 Algol implementation of an indexed sequential file organisation with two levels of index tables.

The system can be regarded as an extension of the set of the high level zone procedures and works within the same framework. It consists of a set of procedures to set up and process an indexed sequential file in an existing backing storage document which has been opened in a zone.

1. The Structure of an Indexed-sequential file on the Backing Storage

The file starts at segment zero of the area and consists of a file head, a bucket table, and a number of buckets. Each bucket except the first occupies segsperbuck consecutive segments.

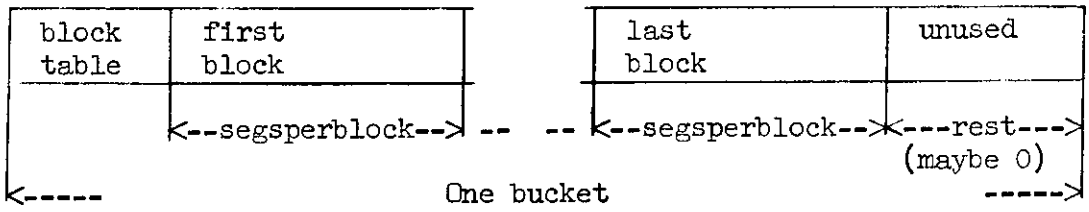
Picture of the file:



The file head and the bucket table occupy an integral number of segments each, and the first bucket occupies only what is left of the first segsperbuck segments.

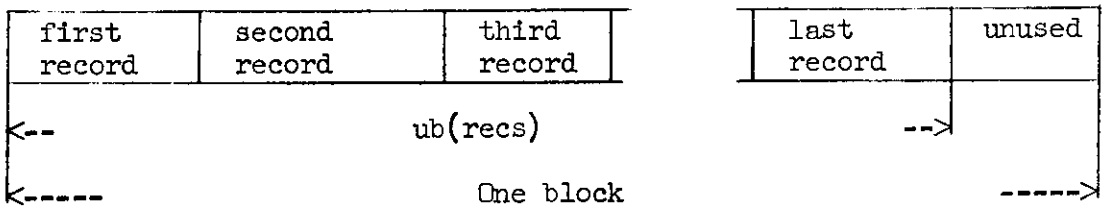
Each bucket consists of a block table, which occupies an integral number of segments, followed by as many whole blocks as there is room for in the bucket, leaving a possible rest unused.
Each block occupies segsperblock consecutive segments.

Picture of one bucket:



Each block consists of an integral number of records (possibly zero) stored tightly together in ascending key order starting at the first byte of the block and leaving a possible rest unused.
ub(recs) denotes the number of bytes used for records, see 1.1.

Picture of one block:



The file head describes the structure of records, blocks, and buckets in a form, which is convenient for the internal logic of the standard procedures processing the file.

The bucket table forms the first level of index tables and contains one entry for each bucket in the file describing the current content of that bucket.

The block tables, one for each bucket, form the second level of index tables. The block table for a given bucket contains one entry for each block in the bucket describing the current content of that block.

The structure and contents of records, index tables, and the file head are described below.

1.1. Records

Each record consists of zero or more user fields, a key consisting of an ordered set of key fields, and maybe a length field. The formats and contents of the user fields are irrelevant to the system. The key- and length-fields are described by code pieces in the file head. These descriptions are common for all records in the file.

Key fields

The key is an ordered set of one or more key fields the value of which is unique identification of the record within the file. Each key field is characterized by a field type, which specifies the size of the key field and how the value of it is represented, and a relative position of the field within the record. The total number of key fields is denoted nkey.

The possible types, the number of bytes in the corresponding key fields, and the values by which they are specified to the system (see 5.5, head_file_i) are:

type:	number of bytes:	value:
12-bit signed integer	1	+ 1
integer	2	∓ 2
long	4	∓ 3
real	4	∓ 4

The sign of the type is used by the comparison rule, see below.

The relative position of a field is the byte number within the record of the last byte of the field, the first byte being byte one.

Comparison rule

The keys of two records can be compared, i.e. the relations key(A) < key(B), key(A) = key(B), and key(A) > key(B) are defined for two records, A and B. If each key is composed of nkey keyfields then the comparison rule is defined by the following (not pure algol) algorithm which compares the key fields, arithmetically according to type, two and two:

```
for i:= 1 step 1 until nkey do
   begin
   compare:= (keyfield(A,i)-keyfield(B,i))×sign(type(i));
   if compare <> 0 then i:= nkey
   end;
```

compare holds now the result of the comparison and we define:

compare < 0 means key(A) < key(B).
compare = 0 means key(A) = key(B).
compare > 0 means key(A) > key(B).

Records are always stored in the file in ascending key order as defined by the above; i.e. in ascending order of the key field values for positive types, but in descending order of the key field values for negative types.

Length field

The length field holds the record length, expressed as number of double word items, and is, just as a key field, characterized by a type and a relative position. Only non-negative types are meaningful for the length field.

If all records in the file have the same length, the length field may be absent. This is specified to the system by a type value = zero, in which case we have

recordlength = maxreclength, see head_file_i, 5.5.

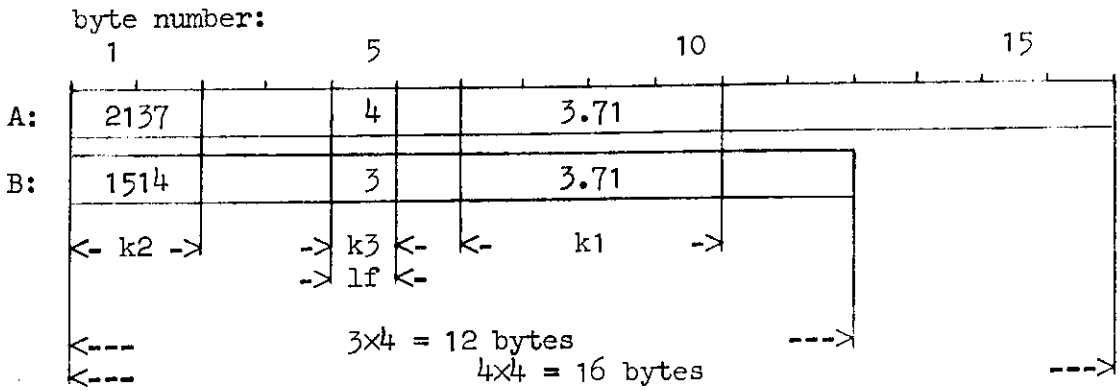
The different fields of a record may overlap each other in any manner as illustrated in the following example where the length field and the third key field occupies the same byte.

Example

Let the key- and length-fields be specified by

	type	relative position
1. key field	4	10
2. key field	-2	2
3. key field	-1	5
length field	1	5

then record A will precede record B in the following picture:



1.2. Block Tables

Each entry in a block table describes one block and consists of the following three fields:

ub(recs): An integer holding the number of bytes occupied by records in the block.

sn(recs): An integer holding the segment number for the first segment of the block.
sn(recs) may thus be regarded as the identification of the physical block.

kp(recs): A composite field consisting of the key fields of a record packed together in consecutive words and with a value such that:
kp(recs) > key(records preceding the block) and
kp(recs) <= key(first record in the block).
kp(recs) may thus be regarded as the identification of the logical block.

The size, in bytes, of one entry in a block table, or in the bucket table, see below, is given by:

entrysize = 4 + keypartsize, where:

keypartsize = 2 × number of words used for key fields in a record.

In the above calculation of keypartsize two successive keyfields of type + 1 are only counted as one word whereas a single keyfield of type $\overline{+}$ 1 counts as a whole word. The algorithm is:

```
keypartsize:= 0;
for i:= 1 step 1 until nkey do
  begin
  fieldsize:= abs type(i);  if fieldsize = 3 then fieldsize:= 4;
  if fieldsize > 1 then keypartsize:= keypartsize + keypartsize mod 2;
  keypartsize:= keypartsize + fieldsize
  end;
keypartsize:= keypartsize + keypartsize mod 2;
```

The block table for a non-empty bucket, i.e. a bucket which contains at least one record, consists of the entries describing non-empty blocks, stored in ascending kp-order, followed by the entries describing empty blocks. In these last entries only the value of sn is relevant as the content of the block itself is undefined.

The size, in bytes, of a block table is given by:

blocktablesize = entrysize × blocksperbuck, where

blocksperbuck = segsize×segsperbuck//(segsize×segsperblock+entrysize);

segsize = number of bytes in one segment = 512.

A block table is stored in an integral number of segments:

segsperblocktable = (blocktablesize -1)//segsize + 1.

1.3. Bucket Table

Each entry in the bucket table describes one bucket and consists of the following three fields:

ub(blocks): An integer holding the relative byte address of the last non-empty entry in the block table for the bucket, the first entry having byte address zero; i.e.:
ub(blocks) = entrysize × (number of nonempty blocks - 1).

sn(blocks): An integer holding the segment number for the first segment of the blocktable for the bucket.
sn(blocks) may thus be regarded as the identification of the physical bucket.

kp(blocks): A composite field consisting of the key fields of a record packed together in consecutive words and with a value such that:
kp(blocks) > key(records preceding the bucket) and
kp(blocks) <= key(first record in the bucket).
kp(blocks) may thus be regarded as the identification of the logical bucket.

entrysize and keypartsize is defined as for the block tables above.

The bucket table consists of a bucket table head followed by the entries describing non-empty buckets, stored in ascending kp-order, followed by the entries describing empty buckets. In these last entries only the value of sn is relevant as the content of the bucket itself is undefined.

The bucket table head consists of five integer fields which describe the current contents of the bucket table and thereby of the whole file:

maxusedbucks: Number of relevant bytes in the bucket table, including the bucket table head; i.e.:
maxusedbucks = entrysize × number of buckets which are or have been nonempty during the lifetime of the file + 10;

recbytes: Total number of bytes occupied by records in the file.

noofrecs: Total number of records in the file.

ub(file): Relative address of the last non-empty entry in the bucket table, the first entry having byte address zero; i.e.:
ub(file) = entrysize × (number of nonempty buckets - 1).

sn(file): Segment number for the first segment of the bucket table. Note that maxusedbucks is the first word on this segment.

The size, in bytes, of the bucket table is given by maxusedbucks, but it is stored in an integral number of segments which can hold a bucket table with maxbucks entries:

```
segsperbucktable = (entrysize×maxbucks + 10 - 1)//segsize + 1;
```

1.4. File Head

The file head describes the structure of the records, blocks, and buckets of the file as specified in the preceding sections. It is generated when the file is created, see 3 , and is unchanged on the backing storage during the lifetime of the file. It is read in to core and modified when the file is prepared for processing, see 4.2 and 4.3.
It holds the following five sections of information:

zonebufrefrel: An integer holding the relative address of the first byte of fileparameters, see below, first byte of zonebufrefrel being byte one. It is used to facilitate references to fileparameters.

kp(save): A composite working field for holding the keypart of a record, size = keypartsize, see 1.2.

savelength: A working field for holding the lengthfield of a record; zero, one, or two words depending on the type of the lengthfield.

recordcodes: The description of the key and lengthfields of a record in the form of code pieces for comparing and moving these fields. The formats and sizes depend on the specification of the key.

fileparameters: Parameters, working locations, and variables describing the records, blocks, and buckets in a format which is independent of the specific file and known by the procedures processing the file. When the file head is read into core some of these parameters are modified to absolute addresses which are used to reference other parts of the zonebuffer, the zone descriptor, and the share descriptors.

The details about the above sections are not given in this paper as they mainly are of interest for the understanding of the internal logic of the system.

The total size, in bytes, of the filehead is the sum of the sizes of each of the above sections and has at present the value:

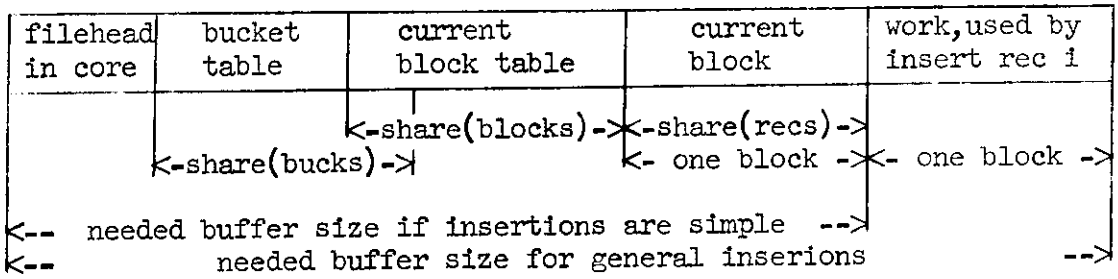
```
fileheadsize =
2 +
keypartsize +
(if lengthtype = 0 then 0 else if lengthtype < 3 then 2 else 4) +
nkey × 24 + number of type three keyfields × 8 +
   (keypartsize + 2)//4×4 + (if lengthtype = 0 then 6 else 14) +
114;
```

The filehead is stored in an integral number of segments, starting at first word of the first segment of the area:

```
segsperhead = (fileheadsize - 1)//segsize + 1.
```

2. An Indexed-sequential File in the Zone Buffer

During the processing of a file, i.e. when a record is available (see), the zone buffer holds in general the following five sections of information:



Filehead holds code pieces, absolute addresses, and other parameters used by the file_i procedures. It is read from the document and modified by init_file_i or start_file_i, see 4.2 and 4.3, and is never written back. It occupies only the necessary fileheadsize bytes and normally not an integral number of segments as in the document.

Bucket table holds the bucket table from the document, including the bucket table head, but only with the number of buckets for which there are room in the document. The buckettablesize thus satisfies the condition:

maxusedbucks <= buckettablesize <= entrysize×maxbucks + 10

The buckettable is read by init_file_i or start_file_i and is only written back if the contents have been changed during the processing, i.e. if records have been deleted or inserted. The bucket table is described in the first share of the zone, denoted share(bucks), as segsperbucktable segments and may thus overlap the next share as shown.

Current block table holds the block table from the last accessed bucket. It occupies segsperblocktable segments and is described in the second share, denoted share(blocks). If the current blocktable has been changed, i.e. records have been inserted or deleted, it will be written back to the document before another block table is read in.

Current block holds the last accessed block from the last accessed bucket. It occupies segsperblock segments and is described in the third share, denoted share(recs). If the current block has been changed, i.e. records have been updated, inserted or deleted, it will be written back to the document before another block is read in.

Work is an area which only is used by insert_rec_i when two blocks are needed in the core at the same time. The third share is then temporarily modified to describe this block. Work need not be present if only simple insertions of new records are needed, see 5.8.

The total minimum size, in bytes, of the zonebuffer is the sum of each of the above sections and has the value:

```
zonebuffersize =
    fileheadsize +
    entrysize × ((segsindocument - 1 ) // segsperbuck + 1) + 10 +
    segsize × segsperblocktable +
    segsize × segsperblock +
    (if simpleinsertions then 0 else segsize × segsperblock)
```

3. The Creation of a File

An empty indexed sequential file with a structure as described in section 1 is created by storing a filehead and a bucket table, describing an empty file, in the first segments of a backing storage area. The file can then later be initialized and processed as described in section 4.

The area

Must be a backing storage area with a segment length of 256 words. It must be opened and closed by explicit calls of the normal standard procedures, open and close, before and after use.

The size of the area is not used before the file is initialized. During creation the are need therefore only to be big enough to hold the file head and the bucket table head, see below.

The file head

Will normally be generated directly into the area by a call of the external algol procedure head_file_i, but it may also be copied from some other document, e.g. if more files with identical structure are needed.

Choice of parameters to head file i

The parameters of head_file_i, see 5.5, determine the storage requirements and running characteristics of the file_i procedures and must be chosen with some care. The following is a survey of the influence of each of the parameters:

recdescr:

nkey: The number of keys determines the size of entries in the bucket table and the block tables and thus influences the size of share(bucks) and share(blocks), see below. The choice between fixed and variable record-length has no significant influence on the running characteristics of the system.

maxreclength: defines the minimum usable free space in a block when insert_rec_i tries to eliminate an overflow. If this parameter is chosen too large insert_rec_i will be forced to take a too pessimistic view on the amount of pushing together necessary and the time used for non-simple insertions will be larger than necessary. In determining whether overflow occurs or not the actual record length is used and maxreclength has no influence. If a small part of a file consists of very long records it may be advantageous to split these to permit the system to run with smaller value of maxreclength.

maxbucks: is used to determine the size of the bucket table on the document. In core the size of the bucket table is determined by the size of the document. The search strategy in the bucket table is optimal when the documents contains maxbucks buckets and too large a value of maxbucks may cause a very slight decrease in the search efficiency.

segsperbuck:
segsperblock:

These parameters (in connection with recdescr) determines the number of blocks per bucket and thus influences the size of the blocktables. Note that share(blocks) occupies an integral number of segments and that certain combinations of blocks per bucket and entrysize therefore gives an inefficient utilization of core store. segsperblock defines the size of share(recs) and the work area. The overall search strategy will be optimal when the actual number of buckets and the number of blocks per bucket both are equal to maxbucks, but the effect on the search efficiency is neglibible in almost all cases.

4. The Processing of a File

The system for processing a file with a structure as described in 1. and 2. consists of one standard integer variable, result_i, and a number of standard procedures, programmed in machine language, and in the following denoted the file_i procs.

The processing of the file may be split up in four phases: opening, initialization or start, record processing, and closing. This section describes these four phases and the general rules for the use of the file_i procs.

4.1. Opening

The file is opened, i.e. connected with a zone, by a call of the normal RC 4000 Algol standard procedure, open.

The number of elements needed in the zone buffer is a function of the structure of the file, the number of segments in the document, and whether or not the full facilities for the insertion of new records is needed. The exact number is given in 3., but to avoid that the programs all should need to know the detailed structure of the file, the system has been augmented by a small external integer procedure, buf_length_i, which yields the needed length.

The number of shares in the zone must be three.

Example 4.1.1.

The zone declaration and the open call for the file <:pip:> may look as follows:

```
begin
...
zone z (buf_length_i (<:pip:>, true), 3, stderror);
...
open (z, 4, <:pip:>, giveup);
...
```

4.2. Initialization

When a new file has been created it must be initialized with an initial set of records which have been sorted in ascending key order. When many records have been inserted by insert_rec_i, see 5.8, further insertions become impossible or their cost excessive indicating that the file should be reorganized. This is done by dumping all the records in the file in ascending key order and using this set of records to initialize the file.

This initialization is prepared by an open call, as described above, followed by a call of init_file_i which will:

- read, check, and modify the file head,
- set up an empty bucket table with as many buckets as there is room for in the document,
- set the share descriptors of the zone to describe the three shares share(bucks), share(blocks), and share(recs), see 2.

The initialization itself is effectuated by successive calls of init_rec_i, each call adding one record to the file, and it must be terminated by a call of one of the procedures set_read_i, set_update_i, or set_put_i. The file is now ready for record processing with the first record of the file available as the zone record, see 4.7.

The initial set of records

The file should be initialized by as many records as possible bebause it is much more time consuming to insert unsorted records one at a time in an already initialized file.

If only a small set of records is available for initialization, they should reflect the final distrubution of keys and they should be spread out uniformly through the file. This may be achieved through proper use of two of the parameters to init_file_i, the buckfactor and the blockfactor.

buckfactor specifies the average number of blocks, useblocks, which init_rec_i should use in each bucket, where:
useblocks = buckfactor × blocksperbuck.

blockfactor specifies the average number of bytes, usebytes, which init_rec_i should use for records in each block, where:
usebytes = segsperblock × segsize × blockfactor.

Example 4.2.1.

The open call in example 4.1.1 may be followed by the call:

```
init_file_i (z, .5, .5)
```

which will specify that init_rec_i only should use half of the blocks in each bucket and half of the bytes in each block. Thus only a quarter of the full capacity of the file can be used during initialization, but the unused capacity will be spread out through the file and thus facilitate later insertions of new records.

4.3. Start

When the file is non-empty, i.e. already has been initialized, processed, and closed, it is reopened for processing by an open call followed by a call of start_file_i which will:

- read, check and modify the file head,
- read the bucket table, compare it with the number of segments in the document, protest if there are fewer buckets than last time the file was processed, and extend the bucket table if there are more,
- set the share descriptors,
- read the first block table and block, and
- return with the first record of the file available as the zone record,

The file is now ready for record processing in read_only_mode, see below.

4.4. Record processing

When the file has been properly initialized or started the individual records can be handled by means of the following procedures:

get_rec_i:	Makes a record with a specified key available.
next_rec_i:	Makes the next record available.
delete_rec_i:	Deletes the available record from the file and makes the next available.
insert_rec_i:	Inserts a new record in its proper place in the file and makes it available.

This processing will take place in one of three modes:

read_only_mode:	Records can not be changed, blocks will only be read and not written.
update_mode:	Records can be changed, all blocks which are read will also be written before a new block is read.
put_mode:	Records may be changed, a call of put_rec_i will ensure that the block containing the current available record will be written back before a new block is read.

Transitions between these three modes are performed explicitly by a call of on of the procedures set_read_i, set_update_i, or set_put_i. Such a call is also used to terminate the initialization or as preparation for close, see below.

4.5. Closing

A call of one of the mode-changing procedures, set_read_i, set_update_i, or set_put_i will ensure that all relevant information is present on the backing storage and the file can therefore, after such a call, be closed by a call of the normal RC 4000 Algol procedure, close.

4.6. Zone state

As the file_i procs assume a specific content of the zone buffer and the share descriptors, the zone should not be used by any procedure outside this system. The following five consecutive values of zone state are therefore reserved to describe a zone when it is used by the file_i procs:

f0+0, read_only_i:	In read_only_mode, except after call of next_rec_i.
+1, read_next_i:	In read_only_mode, after call of next_rec_i.
+2, update_i:	In update_mode
+3, put_i:	In put_mode
+4, initialize_i:	After call of init_file_i or init_rec_i

The zone state is checked by all the file_i procs and an illegal value will terminate the run with an error message.
At present f0 = 10.

4.7. Results

The result of a call of a file_i proc is an integer, delivered in the standard integer variable result_i, and a zone record, the available record.

result i

The value of result_i after a call tells about the overall result of the call; e.g.: whether or not a search for a record succeeded, that the end of the file has been reached, that the record in the call has an improper length field value.

The possible values of result_i and their meanings are listed in the specification for each procedure. These values are, for each procedure, en the range from one and upwards; this makes it easy to switch on result_i or to use it in a case statement.

Available record

During record processing there will always be an available record upon return from the file_i procs. To achieve this the file must always contain at least one record and it will be regarded as cyclic; i.e. a 'wrap-around' will be performed at the end of the file.

The available record is a normal zone record and it has not been copied from the block buffer. The system relies however on the key- and length-fields of the record and saves therefore these before exit and restores them at the next entry; a disastrous effect of an accidental change of these fields is thus avoided.

The effect of changes made in the user fields between calls depends both on the current mode and on how the records happen to be stored in the blocks:

Let a program perform the following sequence of operations on two records, A and B:

```
get_rec_i (z, A);  comment yields an available record, oldA;
change some user fields in the available record giving newA;
get_rec_i (z, B);
get_rec_i (z, A);
```

If A and B happen to be in the same block then the last operation will always yield the changed version of A, i.e. newA.
If A and B are in different blocks then the last operation will yield oldA if we are in readonly-mode or in put-mode but newA if we are in update-mode, because only in the last case will the block containing A have been written when B was accessed.

Another example, this time in put-mode:

```
get_rec_i (z, A); comment yields oldA;
change available record yielding newA;
put_rec_i (z);
change available record yielding newnewA;
```

As the block only is written when a new block is wanted the put_rec_i will include any changes made to the block from it was read-in to a new block is needed; i.e. newnewA will be the latest version of A even though it comes after the put.

In view of the uncontrolable side effects illustrated by the above examples the following rule should be obeyed:

Rule for record-updating

A niece program will only change the contents of the user fields in a record and only in update-mode or put-mode and only when the new version may go out to the file.

4.8. File status

The file head and the bucket table head contain several parameters which describe the overall status of the file; e.g. noofrecs, recbytes, and transports, which is a counter holding the number of input-output operations performed. There are also a few parameters which it is meaningful to change; e.g. the pricelist, see insert_rec_i.

In principle the normal get_zone - set_zone mechanisms could be used to inspect, and even change, any parts of the zone buffer. For safety-reasons these mechanisms should not be used. The system provides therefore two procedures, get_params_i and set_params_i, which allow any part of the zone buffer to be inspected and selected parts to be changed, see these procedures for further details.

4.9. Error Handling

The different kinds of errors and other unnormal situations are treated as follows:

Input-Output

All transports to and from the document are initiated by explicit send-message, but they are waited for and checked by the check routine in the normal Algol running system. Errors and unnormal situations concerning the document are therefore handled as for any other standard input-output, i.e. the block-procedure of the zone and the giveup-mask of the open call have their usual meaning.

Output operations are normally not performed before a new content of a buffer is needed. Whenever the ststem decides that a buffer has to be written before a new read is performed, it notes this by setting a write-operation in the corresponding share. In an emergency situation, e.g. an unexpected termination of the run, the file may therefore be in a bad shape. If the pending write-operations somehow, e.g. by analysis of a core-dump, can be performed, this may repair the situation. The system contains, however, no facilities for this.

Programming Errors

Logical errors, e.g. a wrong zone state value at a procedure call, are treated as programming errors and will terminate the run with a run time alarm.

The possible messages are listed in A3 and they may occur if the Requirements specified for each procedure are not fulfilled when that procedure is called.

Data Errors

Errors in record formats and other unnormal situations arising from the data may be detected by inspection of the result_i value upon return from a procedure call.

The user may also define that specific result_i values from specific file_i-procs should invoke a call of a user specified procedure just before the file_i-proc returns to the main program, see 5.15 for further details.

5. Procedure Specifications

This section contains, in alphabetic order, the specifications of all the procedures offered by the system. To each procedure, except the external ones, is assigned a number, procno_i, by which the procedure is identified in error messages and in the use of the test facilities, see A3 and 5.15 respectively.

A survey of the procedures, in procno_i order, is given in appendix A together with the possible result_i values, their meaning, and the corresponding values of available record.

5.1. External integer procedure buflength_i

Call: buflength_i (filename, full_insert)

buflength_i (return value, integer). Number of doubleworditems needed in the zone buffer for processing the indexed-sequential file given by filename.
filename (call value, string). The name of a backing storage area containing an indexed-sequential file.
full_insert (call value, boolean). True if a buffer with room for general insertions is wanted.

Function: Reads the first segments of the document given by filename into a local zone and computes the needed buflength.

Errors: Uses stderror and giveup = 0. If the needed parameters in the file head do not conform to an indexed-sequential file buflength_i will yield the value zero.

5.2. Procedure delete_rec_i

Call: delete_rec_i (z)

z (call and return value, zone). Specifies the file.

Function: Deletes the available record from the file and makes the successor available.

Requirements: zonestate = update_i or put_i.

Results:
zonestate: if the file became empty then empty_i else unchanged.
procno_i: 9

result_i:	Available record:
1 Deleted	The successor to the available.
2 Deleted, end of file	The first in the file.
3 Not deleted, only one record left	The one

5.3. Integer procedure get_params_i

Call: get_params_i (z) One or more pairs:(paramno, val)

get_params_i (return value, integer). Overall result of call:
0: All parameters processed.
> 0: Exit on error in parameter pair number get_params_i.
z (call value, zone). Specifies the file.
paramno (call value, integer). Identifies the wanted value.
val (return value, integer). Receives the value identified by paramno.

Function: Yields the values of a selected set of parameters from the zone buffer of an indexed-sequential file.
The possible values of paramno and their meanings are listed in appendix B.

Requirements: zone state = any file_i state.

Results: No change of the file.
procno_i: 12

5.4. Procedure get_rec_i

Call: get_rec_i (z, key)

z (call and return value, zone). Specifies the file.
key (call value, real array). A record, at least up to and including all the key fields, with the same key as the one to search. It must be stored in the lexicographically first elements of an arbitrary real array.

Function: Searches a record with the specified key and makes it available.

Requirements: zonestate = read_only_i, read_next_i, update_i, or put_i.

Results:
zonestate: if zonestate = readnext_i then read_only_i else unchanged.
procno_i: 7
result_i:

		Available record:
1	Found	The found.
2	Not found	The successor to the specified.
3	Not found, end of file	The first in the file.

5.5. External procedure head_file_i

Call: head_file_i (z, recdescr, nkey, maxreclength, maxbucks, segsperbuck, segsperblock)

z	(call and return value, zone). Specifies the document to which the generated head is output.
recdesr	(call value, integer array). A two-dimensional array specifying the types and relative positions of the key- and length-fields of records.
nkey	(call value, integer). The number of key fields in records.
maxreclength	(call value, integer). The maximum number of double-word items in a record.
maxbucks	(call value, integer). The maximum number of buckets to provide for in the bucket table of the final file.
segsperbuck	(call value, integer). The number of segments in a bucket in the file. Includes the segments for the block table.
segsperblock	(call value, integer). The number of segments in a block in the file.

Function: Generates the head of an indexed-squential file and a bucket table describing an empty file and outputs it to the document connected with z.

The zone and the document

The zone must be open. Only one share is needed, but it should be able to hold at least nkey × 10 + 35 double-words as one record in an integral number of segments. Note that this zone need not have anything to do with the zone in which the created file later is processed.

The document will be positioned at 0, 0 and the generated file head will be output as at most two blocks by means of outrec.

The content of the file head is independent of the document to which it is output. It may be copied to any number of documents and thus be used as head of different files which use identical record formats and block- and bucket-structure.

Recdescr, nkey, and maxreclength

The array recdescr is assumed to be declared as:

integer array recdescr (1:nkey+1, 1:2)

Each of the first nkey rows describes one key field and row nkey + 1 describes the length rield. The first column holds the field types and the last column the relative positions coded with the values described in 1.1. If we have l = maxreclength × 4 then only the following relative positions are legal:

type:	relative position:
+ 1	1,2,3,...,l-1,l
∓ 2	2,4,6,...,l-2,l
∓ 3	4,6,8,...,l-2,l
∓ 4	4,6,8,...,l-2,l

Constant length records are coded by recdescr(nkey+1, 1) = 0 and recdescr(nkey+1, 2) = anything. The record length is then assumed to be maxreclength.

Example

The record in the example in 1.1 may be described by

```
nkey:= 3;
recdescr(1,1):= 4;     recdescr(1,2):= 10;
recdescr(2,1):= -2;    recdescr(2,2):= 2;
recdescr(3,1):= -1;    recdescr(3,2):= 5;
recdescr(4,1):= 1;     recdescr(4,2):= 5;
```

Errors

head_file_i may terminate the run with a run time alarm.
Possible causes:

recdescr <i> Error detected during processing of field i in recdescr or, if i > 2044, key exceeds capacity of a file head, only possible for nkey > 50.

head_i p <i> Other errors in parameters to head_file_i. The value of i indicates the further cause:

1 Block too small, must at least be able to hold two records of maxlength.

2 Bucket too small, already the first bucket must hold at least one block.

0 Other errors, normally absurd, e.g. negative, parameters.

5.6. Procedure init file i

Call: init_file_i (z, buckfactor, blockfactor)

z (call and return value, zone). Specifies the file.

buckfactor (call value, real). The number of blocks, useblocks, to be used in each bucket during initialization is given by: useblocks = buckfactor × blocksperbuck.

blockfactor(call value, real). The number of bytes, usebytes, to be used in each block during initialization is given by:
usebytes = blockfactor × segsize × segsperblock.

Function: Prepares an indexed-squential file for initialization.

Requirements: zonestate = 0 after opening of an indexed-sequentialfile which may be empty or non-empty.
The zone must have three shares and a sufficiently large buffer, see 4.1.

Results:

zonestate: initialize_i, i.e. ready for init_rec_i.

procno_i: 1

result_i:	Available record:
1 Ready	None
2 Ready, only room for simple insertions in the zone buffer	None

5.7. Procedure init rec i

Call: init_rec_i (z, record)

z (call and return value, zone). Specifies the file.
record (call value, real array). The record to be added stored in the lexicographically first recordlength elements of an arbitrary real array.

Function: Initializes the file with the next of a sorted set of records; buckfactor and blockfactor, which have been specified to init_file_i, will determine when a new bucket or block is taken into use.

Requirements: zonestate = initialize_i after call of init_file_i or init_rec_i.

Results

zonestate: initialize_i, i.e. unchanged.
procno_i: 2

result_i:		Available record
1	Record Added	None.
2	Record not added, file is full	None.
3	Record not added, improper length	None.
4	Record not added, not ascending key	None.

5.8. Procedure insert rec i

Call: insert_rec_i (z, record)

z (call and return value, zone). Specifies the file.
record (call value, real array). The record to be inserted stored in the lexicographically first recordlength elements of an arbitrary real array.

Function: Inserts the specified record in its proper place in the file and makes it available. See below for details.

Requirements: zonestate = update_i or put_i.

Results:

zonestate: unchanged
procno_i: 10

result_i:		Available record:
1	Inserted	The inserted
2	Not inserted, record with the same key already in file.	The one in the file
3	Not inserted, too expensive, can only occur with a modified ensertion strategy, see below.	The successor to the specified
4	Not inserted, file is full	The successor to the specified

5	Not inserted, improper length	The successor to the specified
6	Not inserted, there was no room for the record in the block to which it belonged and the zone buffer is too small for a more complicated insertion, see below.	The successor to the specified

Insertion Strategy

If there is room for the record in the block to which it belongs, it can be inserted without further trouble; otherwise a more complicated strategy is used. This requires an extra block in the zone buffer. Unless this block is present it is therefore pure luck if the insertion succeeds.

The following describes the full insertion strategy, it may be skipped unless you want to modify it.

The organization of the file requires that records are stored in ascending key-order. This means that the insertion of a new record in general will involve a reorganization of some parts of the file in order to get room for the record in the proper block.

The cost of an insertion, in terms of segment transports and other use of resources, depends strongly on how this reorganization is done. The insertion algorithm implements the following scheme which, by taking prices imposed on the involved resources into account, tries to strike a reasonable balance between a fully automatic and a user controlled strategy:

The file head holds a list of relative prices imposed on resources and with initial values assigned by init_file_i or start_file_i:

Name, initial value:	Meaning:
emptybuckprice,	The value of having an empty bucket.
emptyblockprice,	The value of having an empty block.
compressprice,	The initial cost of compressing, i.e. of the pushing together of records in consecutive blocks.
priceperblock,	The cost of (two block transports + central processor time) for one block involved in compressing.
priceperbuck,	The cost of (two block transports + two block table transports + central processor time) for moving an empty block over one bucket.
pricelimit,	The maximum price accepted for an insertion. If the total cost, as computed below, exceeds pricelimit then the insertion will not be done.

These prices is used to compute the total cost of an insertion in step 2, 3, and 4 of the following 7 steps which the algorithm goes through:

1: There is room for the record in the block which it belongs:
The insertion is done without further analysis.

Otherwise the insertion will push one or more records out of the block and thus create an overflow, and:

2: A pushing together of records in at most n consecutive blocks will absorb the overflow:
cost: n × priceperblock + compressprice.
and/or:

3: An empty block, not more than n buckets removed from the current, can be inserted in the block table after the current block and can thus absorb the overflow:
cost: n × priceperbuck + emptyblockprice; n may be zero;
and/or:

4: An empty bucket can be inserted in the bucket table and a block from this bucket used as in 3:
cost: emptybuckprice;
or:

5: None of the situations 2, 3, or 4 exists: The insertion is not possible, the file is regarded as full,
exit with result_i = 4;

6: None of the costs computed in step 2, 3, or 4 are less than pricelimit: The insertion is too expensive,
exit with result_i = 3;

7: The insertion is possible and is done according to the smallest cost;
exit with result_i = 1.

Changing the strategy

A call of set_params_i can be used to set new values in the pricelist. The strategy can thereby be modified within the limits imposed by the above algorithm.

Example 5.8.1.

Let us assume that we want to insert a wholw bunch of, say, 'Jensen's' in a file which is sorted according to first and last name. It may then be useful to force the system to take an empty bucket into use immediately, instead of wasting time on a more and more time consuming compressing. This can be done by assigning a low value to empty buckprice and a high value to compress price.

Example 5.8.2.

In an on-line system it may be necessary to reject insertions which are too time consuming. This can be done by assigning a proper value to pricelimit. The number of rejected insertions may be counted and be used to indicate when a reorganization of the total file is required.

5.9. Procedure next_rec_i

Call: next_rec_i (z)

z (call and return value). Specifies the file.

Function: Makes the next record available.

Requirements: zonestate = read_only_i, read_next_i, update_i, or put_i.

Results:
zonestate: if zonestate = readonly_i then readnext_i else unchanged
procno_i: 8
result_i:
1 Found — Available record: The successor to the available.
2 Found, end of file — The first in the file.

5.10. Procedure put rec i

Call: put_rec_i (z)

z (call and return value, zone). Specifies the file.

Function: Notes that the current block, i.e. the block containing the currently available record, must be written back to the document before a new block is read or the mode is changed.

Requirements: zonestate = update_i or put_i.

Results:
zonestate: unchanged
procno_i: 11
result_i:
1 Done — Available record: Unchanged

5.12. Integer procedure set params i

Call: set_params_i (z) One or more pairs:(paramno, val)

set_params_i (return value, integer). Overall result of the call:
0: All parameters processed.
> 0: Exit on error in parameter pair number set_params_i.
z (call and return value, zone). Specifies the file.
paramno (call value, integer). Identifies the parameter in the zone buffer to which val is assigned.
val (call value, integer). The value to be assigned to the parameter identified by paramno.

Function: Assigns values to a selected set of parameters in the zone buffer of an indexed-sequential file.
The possible values of paramno and their meanings are listed in appendix B.

Requirements: zonestate = any file_i state.

Results: Affects only the parameters assigned to.
procno_i: 13

5.13. Procedure set put i

Call: set_put_i (z)

z (call and return value, zone). Specifies the file.

Function: Terminates the current mode and sets put-mode.

Requirements: zonestate = any file_i state except empty_i.

Results:

zonestate: put_i.
procno_i: 5

result_i:	Available record:
1 Normal mode change	Unchanged.
2 Initialization terminated	The first in the file.

5.14. Procedure set read i

Call: set_read_i (z)

z (call and return value, zone). Specifies the file.

Function: Terminates the current mode and sets readonly-mode.

Requirements: zonestate = any file_i state except empty_i.

Results:

zonestate: read_only_i
procno_i: 4

result_i:	Available record:
1 Normal mode change	Unchanged.
2 Initialization terminated	The first in the file.

5.15. Integer procedure set test i

Call: set_test_i (z) Optional parameter:(test_proc)
One or more pairs:(procno_i, results)

set_test_i (return value, integer). Overall result of call:
-1: Exit on error in first parameter.
0: All parameters processed.
> 0: Exit on error in parameter pair number set_test_i.

z (call and return value, zone). Specifies the file.

test_proc (cal value, procedure). The name of a procedure which must be declared at the same level as the zone or at an outer level.
It must conform to the declaration:

```
procedure test_proc (z, record, procno_i);
     zone z; array record; integer procno_i;
```

It will, when specified, see below, be called just before the exit from a file_i proc with the following parameters:

z: The zone of the file_i proc call.

record: The array of the file_i proc call or, if not present, the zone z.

procno_i: The identification of the file_i proc.

The parameter test_proc may be left out if it already has been given in a previous call of set_test_i.

procno_i (call value, integer). Specifies the result_i values for which test_proc should be called upon exit from the file_i proc identified by procno_i. Any number of result_i values can be specified in one parameter by representing each result_i value as one digit in the decimal representation of results.

Function: Specifies a procedure to be called upon exit from certain file_i procs with certain result_i values.

The parameter pairs, procno_i - results, are processed in order and only specified changes in the situation will be effectuated but with the following additional conventions:

procno_i = 0 denotes all file_i procs,

results = 0 denotes clearing of all priviously specified result_i values for procno_i.

Non-existing result_i values are ignored.

Requirements: zonestate = any file_i state.

Results: Affects only the test situation.

procno_i: 14

Examples:

The call
set_test_i (z, 0, 0)
will prevent any further calls of the current test_proc.

The call
set_test_i (z, testit, 0, 123456)
will ensure that the procedure testit will be called upon exit from any file_i proc with any result_i and thus provide a means for supervising the main program.

The call
set_test_i (z, through, 0, 0, 8, 2)
will invoke a call of the procedure through when, and only when next_rec_i has reached the end of the file.
next_rec_i, procno_i = 8, yields result_i = 2 at end of file.

5.16. Procedure set_update_i

Call: set_update_i (z)

z (call and return value, zone). Specifies the file.

Function: Terminates the current mode and sets update-mode.

Requirements: zonestate = any file_i state except empty_i.

Results:

zonestate: update_i.
procno_i: 6
result_i:

1	Normal mode change	Available record: Unchanged.
2	Initialization terminated	The first in the file.

5.17. Procedure start file i

Call: start_file_i (z)

z (call and return value, zone). Specifies the file.

Function: Prepares an indexed-sequential file for record processing.

Requirements: zone state = 0 after opening of an indexed-sequential-file containing at least one record.
The document must hold at least the same number of buckets as was used last time the file was open, it may hold more.
The zone must have three shares and a sufficiently large buffer, see

Results:

zonestate: readonly_i, i.e. readonly-mode.
procno_i: 3
result_i:

1	Record available	Available record: The first in the file.
2	Record available, only room for simple insertions in the zone buffer.	The first in the file.

Appendix A. Survey of the Procedures Offered by the System

A1. For Creation and Opening of an Indexed-sequential File

head_file_i (see 5.5). External procedure which generates a file head.

buflength_i (see 5.1). External procedure which yields the buffer size needed for processing a file.

A2. For Processing an Indexed-sequential File

Each procedure is described below in order of their identification number, procno_i, and with possible values of result_i and available record.

procno_i, name	result_i value and meaning	Available record
1, init_file_i	1 Ready	None
	2 Ready, short buffer	None
2, init_rec_i	1 Record added	None
	2 File is full	None
	3 Improper length	None
	4 Not ascending key	None
3, start_file_i	1 Ready	First in file
	2 Ready, short buffer	First in file
4, set_read_i	1 Ok	Unchanged
	2 Ok, after initialization	First in file
5, set_put_i	1 Ok	Unchanged
	2 Ok, after initialization	First in file
6, set_update_i	1 Ok	Unchanged
	2 Ok, after initialization	First in file
7, get_rec_i	1 Found	The found
	2 Not found	The successor
	3 Not found, end of file	First in file
8, next_rec_i	1 Found	The next in the file
	2 Found, end of file	First in file
9, delete_rec_i	1 Deleted	The next in the file
	2 Deleted, end of file	First in file
	3 Not deleted, one record left	The one left
10, insert_rec_i	1 Inserted	The inserted
	2 Already in file	The one in the file
	3 Too expensive	The successor
	4 File is full	The successor
	5 Improper length	The successor
	6 Short buffer	The successor
11, put_rec_i	1 Done	Unchanged

The following utility procedures do not change result_i or available record and they can not invoke a call of the test_proc:

12, get_params_i

13, set_params_i

14, set_test_i

A3. Alphabetic List of Alarm Causes

The system adds the messages below to the list of possible alarm causes from the standard procedures of RC 4000 Algol.

head i p <i> Parameter error in call of head_file_i:
- i = 1: Not room for two records in a block.
- 2: Not room for at least one block in the first bucket.
- 0: Other illegal parameter values.

prep i <i> Error during init_file_i, init_rec_i, or start_file_i:
- i = 1: Too few segments in the document.
- 2: The bucket head is not consistent.
- 3: Too small a zone buffer.
- 4: The file head is not consistent.
- 5: Not three shares.
- 6: Zone state <> 0.
- 7: Empty file after start_file_i or mode change.

recdescr <i> Error or inconsistency in the record description in the call of head_file_i.
- i < 2044: Error in field i.
- i >= 2044: Key too big.

state i <i> Zonestate error in call of any file_i proc:
- i = zonestate × 100 + procno_i.

Appendix B. Parameters in the Zone Buffer

The lists below defines the values of paramno to be used in calls of get_params_i or set_params_i.
The lists may be extended when it appears that more parameters are of interest to the user.

B1. paramno values to get params i:

paramno, name, meaning

1,	recsinfile	Number of records in the file
2,	recbytes	Number of bytes used for records
3,	transports	Number of input or output operations performed since the processing was started.
4,	pricelimit	For 4 - 9, see 5.8, insert_rec_i.
5,	emptybuckprice	
6,	emptyblockprice	
7,	compressprice	
8,	priceperblock	
9,	priceperbuck	
10,	computed cost	The cost computed in the last call of insert_rec_i

B2. paramno values to set params i:

The following of the parameters above may also be assigned to by set_params_i with values in the intervals shown:

paramno, name, legal values

4,	pricelimit	0 <= val <= upper limit for integers
5,	emptybuckprice	0 <= val < 2048
6,	emptyblockprice	0 <= val < 2048
7,	compressprice	0 <= val < 2048
8,	priceperblock	0 <= val < 2048
9,	priceperbuck	0 <= val < 2048