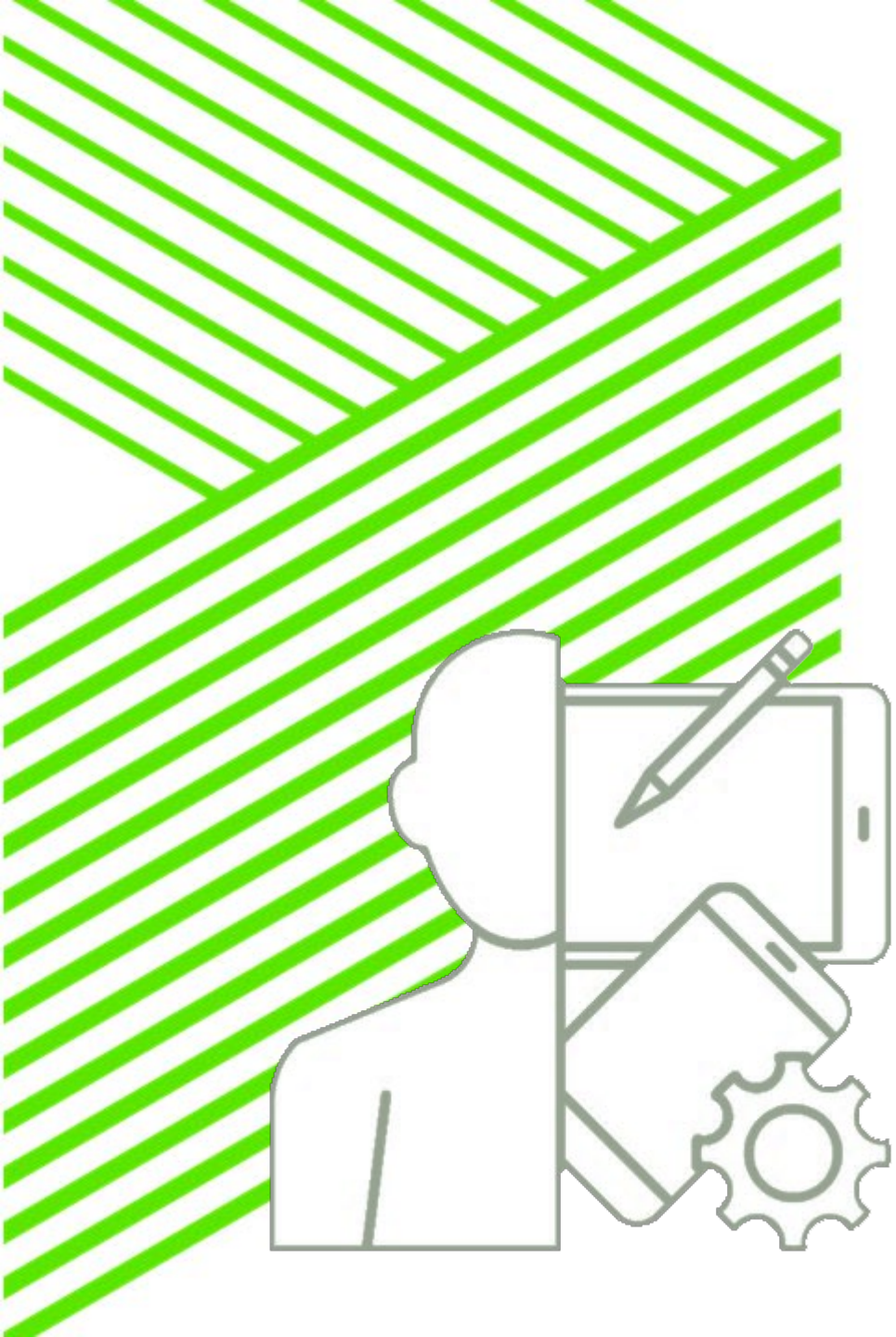


Deep Down Indexing

You don't know *beep* about indexes

compile-listing ain’t enough

- Intro
- Useful Tools:
  - LOG-MANAGER, ProTop, -zqil, XREF
- Index selection basics: AND
- (((Index) AND (selection) OR (maybe not))
  - OR branches and parentheses
- Some subtleties: casing, unknowns, temp-tables
- Conclusion

Paul (Koufalis)

- Progress DBA and UNIX admin since 1994
- Expert OpenEdge technical consulting
- Wide range of experience
  - Small 10 person offices to 3500+ concurrent users
  - AIX, HPUX, Linux, Windows…if Progress runs on it, I've worked on it
- Father to these two monkeys

pk@wss.com

White Star Software

- The oldest and most respected independent DBA consulting firm in the world
- Five of the world's top OpenEdge DBAs
- Author of ProTop, the #1 FREE OpenEdge Database Monitoring Tool

  http://protop.wss.com

The Compiler constructs a logical tree from a query and evaluates both sides of each AND or OR, looking for index criteria. ABL counts equality, range, and sort matches (for OR) and uses them to select and bracket indexes.

The precise rules are numerous and complex, and it is not important to fully understand their details.

OpenEdge® Web Paper: ABL Database Triggers and Indexes

Help! I need somebody!

test and verify? how !?!

Given a simple query

```
for each order no-lock where salesrep begins 'd'
```

- ProTop of course. It's free.

Index Activity

Idx#	Area#	Index Name	Lvls	Blocks	Util	Idx Root	Create	Read v
45	8	Order.SalesRep	2	358	51%	77952	0	182915

- Query object handle

```
q:index-information(1) = SalesRep
```

- Log-manager - see next slides

log-manager

- A terribly underused but awesomely amazing tool
- Allows you to leave debug messages in your code
  - No more `/* Message here vValue. */`
- Create some secret hotkey sequence to activate
  - I.e. you can turn it on in production for one user
- Writes detailed info to a log file

```
assign log-manager:logfile-name    = "c:\temp\wshop.log"
       log-manager:logging-level   = 3  // There are more levels than you think
       log-manager:log-entry-types = "4GLTrace,4GLTrans,QryInfo".
```


test and verify with log-manager

- Still with our `for each order no-lock where salesrep begins 'd'` example:

```
Type: Dynamically Opened Query
PREPARE-STRING: for each order no-lock where salesrep begins 'd'
Prepared at Runtime
Client Sort: N
Scrolling: Y
Table: sports2000.Order
  Indexes: SalesRep
Times prepared: 1
Time to prepare (ms): 0
DB Blocks accessed:
  sports2000 : 366074
DB Reads:
  Table: sports2000.Order : 182913
  Index: Order.SalesRep : UNAVAILABLE
```


test and verify using protop

Table Activity

Tbl#	Area#	Table Name	RM Chain	#Records	Turns	Create	Read v	Update	Delete	OS Read
> 790	20	s_crm-valid-queue	60	1193966	0.16	0	194453	0	0	0
936	18	wm-send	16	5368656	0.00	0	341	0	0	0
782	20	s_crm-crm-field	60	48	0.52	0	25	0	0	0
787	20	s_crm-lat-field	60	48	0.36	0	17	0	0	0
849	22	wb_dept-user	60	7088	0.00	0	12	0	0	0
798	20	s_param	39	1979	0.00	0	8	0	0	0
169	20	cost-factor	60	18	0.39	0	7	0	0	0
528	18	prod-exp	37	217216	0.00	0	7	0	0	0
557	18	product	1355	214159	0.00	0	7	0	0	0
654	142	so-pick-d	383	28455997	0.00	0	7	0	0	0
1	22	alternate	58	488	0.00	0	0	0	0	0
2	18	am-list	60	2	0.00	0	0	0	0	0
3	8	am-list-d	4		0.00	0	0	0	0	0

Index Activity

Idx#	Area#	Index Name	Lvls	Blocks	Util	Idx Root	Create	Read v	Split	Delete	BlkDl	Note
1456	19	so-pick.ctrl-machine	3	969	90%	9535	0	68	0	0	0	
1463	19	so-pick.shipped	2	292	98%	9983	0	65	0	0	0	
4	6	_Field._Field-Position	0	0	0%	68416	0	51	0	0	0	U
6	6	_Index-Field._Index/Number	0	0	0%	68544	0	36	0	0	0	PU
1734	21	s_crm-crm-field.s_crm-crm-field	1	1	6%	35263	0	26	0	0	0	PU
1816	23	wb_dept-user.wb_user	2	36	50%	13439	0	23	0	0	0	
5	6	_Index._File/Index	0	0	0%	68480	0	11	0	0	0	PU
2	6	_Field._File/Field	0	0	0%	68288	0	2	0	0	0	PU
1196	121	prod-exp-loc-d.prod-exp-loc-d	4	147,490	70%	127	0	0	0	0	0	PU

Index Activity

Idx#	Area#	Index Name	Lvls	Blocks	Util	Idx Root	Create	Read v
45	8	Order.SalesRep	2	358	51%	77952	0	182915

User IO Activity

Usr#	Tenant	Name	PID	Flags	Blk Ac v	OS Rd	OS Wr	Hit%	Rec Lck	Rec Wts	Line#	Program Name
> 773	0	trarm	48139	SXB*	390366	0	0	100.00%	194492	0	582	crmim/apply.p
778	0	xuycata2	13742	SX	1411	0	0	99.99%	1	0	305	so/bmonaut1.p
772	0	xcl1wt2	21791	SXB	1291	0	0	100.00%	169	0	-1	wm/senddata.p
783	0	m1wt2	6278	SXB	200	0	0	100.00%	0	0	-1	wm/senddata.p

-zqil

- Unsupported and undocumented startup parameter
  - Aren't those the best!?!
- Writes detailed run-time index usage information to db.lg - yes db.lg

  - **Do NOT use in PRODUCTION**

- Tells you which index is used and how many fields deep
- Presented as number of lower brackets and upper brackets
  - GT and GE are lower brackets: they define a lower boundary for the index field
  - LT and LE are upper brackets: they define an upper boundary for the index field

Index basics

but before we get to the rules…

- This only applies to ABL and not SQL
- Rules are applied in hierarchical order to filter indexes
  - This is important: Each rule is applied and the result is one or more ***remaining*** indexes
  - Use a worksheet approach to make the rules "easy" to apply

- The first 7 rules only apply to a subset of indexes
  - Compiler scans all fields in the query and selects all indexes that have leading components with those fields

- Field match rules must be contiguous
  - “Equality” on fields 1 and 3 of the index counts as 1, not 2

Rules continue to be applied until there is only one index left

but before we get to the rules…

```
Table: Customer
      sRepStateCity          8        3 + SalesRep  + State + City
w     Comments               8        1 + Comments
      CountryPost            8        2 + Country   + PostalCode
pu    CustNum                8        1 + CustNum
      Name                   8        1 + Name
      SalesRep               8        1 + SalesRep
      sRepState              8        2 + SalesRep  + State
      CustNumUseless         8        2 + CustNum   + SalesRep

FOR EACH Customer WHERE State = 'Leinster' AND City = 'Dublin'

// The sSrepStateCity index is NOT eligible for selection
// NO indices are pre-selected for this query
```

- Field match rules must be contiguous
- “Equality” on fields 1 and 3 of the index counts as 1, not 2

Rules continue to be applied until there is only one index left

the rules

For the first-pass set of indexes, filter using the following rules:

1. Pre-select only indexes with leading components in the where clause
2. If `CONTAINS` use word-index
3. Unique index with all components involved in the equality matches
4. Complete equality matches in > 1 index: all index components involved in the equality matches
5. Most active equality matches
6. Most active range matches
7. Most active sort matches

If multiple indexes remain, select one from

8. The primary index
9. First index alphabetically by name

the rules

For the first-pass set of indexes, filter using the following rules:

1. Pre-select only indexes with leading components in the where clause
2. If `CONTAINS` use word-index
3. Unique index with all components involved in the equality matches
4. Complete equality matches in > 1 index: all index components involved in the equality matches
5. Most active equality matches
6. Most active range matches
7. Most active sort matches

If multiple indexes remain, select one from

8. The primary index
9. First index alphabetically by name

>1

Superset Selector
If there are indexes that will select supersets of records that are selected by other indexes, then we eliminate those.

Sort Selector Skip
Index records are already sorted by the index fields, so we don't need to reevaluate

order table indexes

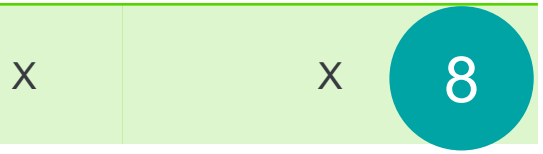
Table	Records	Size	Size	Count	LOBs	Size	Mean
PUB.Order	727285	63.9M	92	727285	--	--	--

Indexes

Flags	Index Name	Cnt	Field Name
u	CustOrder	2	+ CustNum + Ordernum
	OrderDate	1	+ OrderDate
pu	OrderNum	1	+ Ordernum
	OrderStatus	1	+ OrderStatus
	SalesRep	1	+ SalesRep
w	SRepW	1	+ SalesRep
	SRepDate	2	+ SalesRep + OrderDate
	DateSRep	2	+ OrderDate + SalesRep
	SDateOstat	2	+ ShipDate + OrderStatus

for each order

Selection Rule \ Index	U CustOrder	OrderDate	PU OrderNum	OrderStatus	SalesRep	W sRepW	SRepDate	DateSRep	SDateOstat
If “CONTAINS”, use word-index	X	X	X	X	X		X	X	X
Unique index with all components involved in the equality matches	X	X	X	X	X		X	X	X
Complete equality match	X	X	X	X	X		X	X	X
Most active equality matches	X	X	X	X	X		X	X	X
Most active range matches	X	X	X	X	X		X	X	X
Most active sort matches	X	X	X	X	X		X	X	X
The primary index			✓						
First index alphabetically by name									



```
where salesrep = "BBB"
```

Index / Selection Rule	U CustOrder	PU OrderDate	PU OrderNum	PU OrderStatus	W SalesRep	W sRepW	W SRepDate	DateSRep	SDateOstat
If “CONTAINS”, use word-index					X		X		
Unique index with all components involved in the equality matches					X		X		
Complete equality match					✓				
Most active equality matches									
Most active range matches									
Most active sort matches									
The primary index									
First index alphabetically by name									

2

```
where salesrep = "DKP" and orderdate = 09/05/2011
```

Index / Selection Rule	U CustOrder	OrderDate	PU OrderNum	OrderStatus	SalesRep	W sRepW	SRepDate	DateSRep	SDateOstat
If “CONTAINS”, use word-index		X			X		X	X	4
Unique index with all components involved in the equality matches		X			X		X	X	
Complete equality match							X	X	⊇ 2
Most active equality matches							X	X	
Most active range matches							X	X	
Most active sort matches							X	X	
The primary index							X	X	
First index alphabetically by name								✓	

where salesrep = "DKP" and orderdate = 09/05/2011 by salesrep

Index / Selection Rule	U CustOrder	OrderDate	PU OrderNum	OrderStatus	SalesRep	W sRepW	SRepDate	DateSRep	SDateOstat
If “CONTAINS”, use word-index		X			X		X	X	4
Unique index with all components involved in the equality matches		X			X		X	X	
Complete equality match							X	X	2
Most active equality matches							X	X	
Most active range matches							X	X	
Most active sort matches							X	X	
The primary index							X	X	
First index alphabetically by name								✓	

```
where salesrep = "BBB" and orderStatus = "Shipped"
```

Index / Selection Rule	U CustOrder	OrderDate	PU OrderNum	OrderStatus	SalesRep	W sRepW	SRepDate	DateSRep	SDateOstat
If “CONTAINS”, use word-index				X	X		X		3
Unique index with all components involved in the equality matches				X	X		X		
Complete equality match				✓	✓				>1
Most active equality matches									
Most active range matches									
Most active sort matches									
The primary index									
First index alphabetically by name									

where salesrep >= "DKP" and orderdate >= 09/05/2011 by salesrep

Index / Selection Rule	U CustOrder	OrderDate	PU OrderNum	OrderStatus	SalesRep	W sRepW	SRepDate	DateSRep	SDateOstat
If “CONTAINS”, use word-index		X			X		X	X	4
Unique index with all components involved in the equality matches		X			X		X	X	
Complete equality match		X			X		X	X	
Most active equality matches		X			X		X	X	
Most active range matches					X		X	X	3
Most active sort matches					X		X		
The primary index									
First index alphabetically by name					✓				

```
where orderdate = 09/05/2011
```

Index / Selection Rule	U CustOrder	OrderDate	PU OrderNum	OrderStatus	SalesRep	W sRepW	SRepDate	DateSRep	SDateOstat
If “CONTAINS”, use word-index		X						X	
Unique index with all components involved in the equality matches		X						X	
Complete equality match		X						X	
Most active equality matches		X						X	
Most active range matches		X						X	
Most active sort matches		X						X	
The primary index		X						X	
First index alphabetically by name								✓	

2

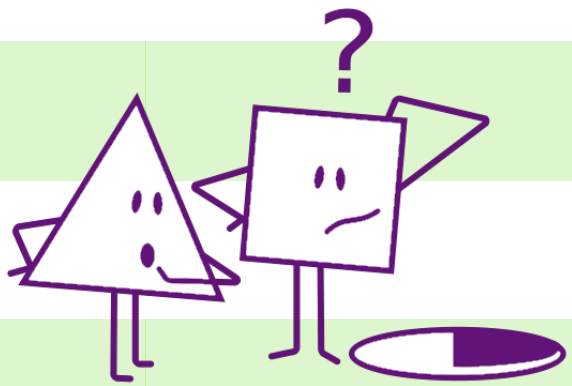
```
where orderdate = 09/05/2011 and shipdate = 10/01/2011
```

Index / Selection Rule	U CustOrder	OrderDate	PU OrderNum	OrderStatus	SalesRep	W sRepW	SRepDate	DateSRep	SDateOstat
If “CONTAINS”, use word-index		X						X	X
Unique index with all components involved in the equality matches		X						X	X
Complete equality match		X						X	X
Most active equality matches		X						X	X
Most active range matches		X						X	X
Most active sort matches		X						X	X
The primary index		X						X	X
First index alphabetically by name								✓	

```
where orderdate = 09/05/2011 and shipdate = 10/01/2011
```

Selection Rule \ Index	U CustOrder	OrderDate	PU OrderNum	OrderStatus	SalesRep	W sRepW	SRepDate	DateSRep	SDateOstat
If “CONTAINS”, use word-index		X						X	X
Unique index with all components involved in the equality matches		X						X	X
Complete equality match		X						X	X
Most active equality matches									
Most active range matches									
Most active sort matches									
The primary index									
First index alphabetically by name									

3



```
src\ lab_2.p src\lab_2.p 13 SEARCH bigsports.Order OrderDate
```

gotchas

- Expressions break bracketing

```
FOR EACH order NO-LOCK WHERE MONTH(orderDate) = 1 ...
```

- `BEGINS` does NOT break bracketing
  - Considered a range bracket

```
FOR EACH order NO-LOCK WHERE salesRep BEGINS "D"
```

  - Uses the `order.salesRep` index

- `MATCHES` breaks bracketing

- When in doubt, test and verify

```
where month(orderDate) > 6
```

Index / Selection Rule	U CustOrder	OrderDate	PU OrderNum	OrderStatus	SalesRep	W sRepW	SRepDate	DateSRep	SDateOstat
If “CONTAINS”, use word-index	X	X	X	X	X		X	X	X
Unique index with all components involved in the equality matches	X	X	X	X	X		X	X	X
Complete equality match	X	X	X	X	X		X	X	X
Most active equality matches	X	X	X	X	X		X	X	X
Most active range matches	X	X	X	X	X		X	X	X
Most active sort matches	X	X	X	X	X		X	X	X
The primary index			✓						
First index alphabetically by name									

8

That's all … OR?

customer table indexes

```
Table              Records    Size   Size  Count       LOBs   Size   Mean
PUB.Customer       201120    31.1M 162   201120       --     --     --
Indexes
Flags Index Name          Cnt  Field Name
w     Comments                  10          1 + Comments
      Country                   9           1 + Country
      CountryPost               10          2 + Country
                                              + PostalCode
pu    CustNum                   10          1 + CustNum
      Name                      10          1 + Name
      SalesRep                  10          1 + SalesRep
      SrepCountryCLimit         9           3 + SalesRep
                                              + Country
                                              + CreditLimit
```

oh really?

What indexes are used?

```
for each Customer where Customer.Name = "Koufalis" or Customer.SalesRep = "BBB"
```


oh really?

What indexes are used?

```
for each Customer where Customer.Name = "Koufalis" or Customer.SalesRep = "BBB"
```

- If you guessed **`Name`** , bravo.
- If you guessed **`SalesRep`** , bravo.
- Validate with `COMPILE ... XREF`

```
custom.p 45 ACCESS sports2000.Customer Name
custom.p 45 ACCESS sports2000.Customer Name
custom.p 45 STRING "Koufalis" 8 NONE TRANSLATABLE
custom.p 45 STRING "BBB" 5 NONE TRANSLATABLE
custom.p 45 SEARCH sports2000.Customer Name
custom.p 45 SEARCH sports2000.Customer SalesRep
```


oh really?

```
for each Customer where Customer.Name = "Koufalis" or Customer.Name = "Judge"
```

What indexes are used?

oh really?

```
for each Customer where Customer.Name = "Koufalis" or Customer.Name = "Judge"
```

What indexes are used?

- If you guessed **Name** , bravo.

- Validate with `COMPILE ... XREF`

```
custom.p 45 ACCESS sports2000.Customer Name
custom.p 45 ACCESS sports2000.Customer Name
custom.p 45 STRING "Koufalis" 8 NONE TRANSLATABLE
custom.p 45 STRING "Judge" 5 NONE TRANSLATABLE
custom.p 45 SEARCH sports2000.Customer Name
custom.p 45 SEARCH sports2000.Customer Name
```


Wut.

the OR operator makes a difference

Each side of an `OR` is its own, distinct index selection operation

```
for each customer where Customer.Name = "Koufalis" or Customer.SalesRep = "BBB"
```

- 2 distinct index selection operations

```
for each customer where Customer.Name = "Koufalis" or Customer.Name = "Judge"
```

- This is *also* 2 distinct index selection operations

- A "logic tree" is built until we hit an **`AND`**. Break down the query until we hit **`AND`**s
- This implies that we can force multiple indexes to be used via **`OR`**s and parentheses
- Now we apply our rules to the **`AND`** part of the logic tree, as above

simple OR clause

```
for each customer where
customer.Name = "Koufalis"          or          customer.SalesRep = "BBB"
```

Index / Selection Rule	PU CustNum	CountryPost	Name	SalesRep	W Comments	SRepDate	sRepState	
If “CONTAINS”, use word-index			X					1
Unique index with all components involved in the equality matches			X					
Complete equality match			✓					
Most active equality matches								
Most active range matches								
Most active sort matches								
The primary index								
First index alphabetically by name								

Index / Selection Rule	PU CustNum	CountryPost	Name	SalesRep	W Comments	SRepDate	sRepState	
If “CONTAINS”, use word-index				X		X	X	3
Unique index with all components involved in the equality matches				X		X	X	
Complete equality match				✓				
Most active equality matches								
Most active range matches								
Most active sort matches								
The primary index								
First index alphabetically by name								

```
custom.p 45 ACCESS sports2000.Customer Name
custom.p 45 ACCESS sports2000.Customer Name
custom.p 45 STRING "Koufalis" 8 NONE TRANSLATABLE
custom.p 45 STRING "BBB" 5 NONE TRANSLATABLE
custom.p 45 SEARCH sports2000.Customer Name
custom.p 45 SEARCH sports2000.Customer Salesrep
```


simple OR clause

```
for each customer where
customer.Name = "Koufalis"          or          customer.Name = "Judge"
```

Index / Selection Rule	PU CustNum	CountryPost	Name	SalesRep	W Comments	SRepDate	sRepState
If “CONTAINS”, use word-index			X				1
Unique index with all components involved in the equality matches			X				
Complete equality match			✓				
Most active equality matches							
Most active range matches							
Most active sort matches							
The primary index							
First index alphabetically by name							

Index / Selection Rule	PU CustNum	CountryPost	Name	SalesRep	W Comments	SRepDate	sRepState
If “CONTAINS”, use word-index			X				1
Unique index with all components involved in the equality matches			X				
Complete equality match			✓				
Most active equality matches							
Most active range matches							
Most active sort matches							
The primary index							
First index alphabetically by name							

```
custom.p 45 ACCESS sports2000.Customer Name
custom.p 45 ACCESS sports2000.Customer Name
custom.p 45 STRING "Koufalis" 8 NONE TRANSLATABLE
custom.p 45 STRING "Judge" 5 NONE TRANSLATABLE
custom.p 45 SEARCH sports2000.Customer Name
custom.p 45 SEARCH sports2000.Customer Name
```


complex OR with parentheses (1)

How many "simple clauses" are here?

```
for each Customer where
 ( Customer.Name = 'Koufalis' or
    ( Customer.Country = 'AAA' or
       (  Customer.Name = 'Koufalis' and Customer.Country = 'DEN')
    )
 )
or
( Customer.Salesrep = 'BBB' and  Customer.Salesrep = 'XXX' )
```


complex OR with parentheses (1)

How many "simple clauses" are here?

```
for each Customer where
 ( Customer.Name = 'Koufalis' or
    ( Customer.Country = 'AAA' or
       (  Customer.Name = 'Koufalis' and Customer.Country = 'DEN')
    )
 )
or
( Customer.Salesrep = 'BBB' and  Customer.Salesrep = 'XXX' )
```

1	Name
2	Country
3, 4	Country, Name
5	Srep

```
custom.p 45 SEARCH sports2000.Customer Name
custom.p 45 SEARCH sports2000.Customer Country
custom.p 45 SEARCH sports2000.Customer Country
custom.p 45 SEARCH sports2000.Customer Name
custom.p 45 SEARCH sports2000.Customer Srep
```


complex OR with parentheses (2)

How many "simple clauses" are here?

```
for each Customer where
 ( Customer.Name = 'Koufalis' or
    ( Customer.Country = 'AAA' or
       (  Customer.Name = 'Koufalis' and
              (Customer.Country = 'DEN' or Customer.Country = 'USA' )
       )
    )
 )
or
( Customer.Salesrep = 'BBB' and  Customer.Salesrep = 'XXX' )
```


complex OR with parentheses (2)

How many "simple clauses" are here?

```
for each Customer where
 ( Customer.Name = 'Koufalis' or
    ( Customer.Country = 'AAA' or
       (  Customer.Name = 'Koufalis' and
              (Customer.Country = 'DEN' or Customer.Country = 'USA' )
       )
    )
 )
or
( Customer.Salesrep = 'BBB' and  Customer.Salesrep = 'XXX' )
```

1 Name

2 Country

3 Name

4 Srep

```
46 SEARCH sports2000.Customer Name
46 SEARCH sports2000.Customer Country
46 SEARCH sports2000.Customer Name
46 SEARCH sports2000.Customer SalesRep
```


But wait! There's more!

indexes and unknown values

- Unique indexes enforce a constraint of a one value per index-field per table …

  BUT multiple unknown values in ABL are allowed

- If you want truly unique values, mark the field(s) in the index as mandatory.

- Index field(s) containing unknown values sort **higher** than any other value

```
create Customer.
assign Customer.custnum = 1
       Customer.name    = 'Peter'.

create Customer.
assign Customer.custnum = 2
       Customer.name    = 'Paul'.

create Customer.
assign Customer.custnum = ?
       Customer.name    = 'Mary'.
```

```
for each Customer by CustNum desc:

CustNum         Name
--------------- --------------
              ?         Mary
              2         Paul
              1         Peter
```


indexes and case sensitivity

- By default, the AVM doesn't care about case for fields (whether indexed or not)
  - Field (data) values are stored as entered
  - Index field values are stored in UPPER CASE

```
"Paul" = "PAUL" = "paul"
```

```
--------------------------
Error (Press HELP to view stack trace)
--------------------------
** Customer already exists with  "Paul".
(132)
--------------------------
OK   Help
--------------------------
```

- If the fields are case sensitive
  - Field (data) values are stored as entered
  - Index field values are stored as entered

```
"Paul" <> "PAUL" <> "paul"
```

  - Sorting on these fields may differ
  - Word indexed fields are always treated as case-insensitive

when no index is needed

```
find Customer where rowid(Customer) eq 0xDEADBEEF
```

- Fast, non-indexed record access
- `ROWID` is the new `RECID`
  - The value can change - only use for temporary/short-lived use

```
for each Customer table-scan
```

- Fast, non-indexed record access for temp-tables or db tables in Type 2 storage
- If the AVM could select an index with the first 5 rules, it will warn you at COMPILE time
- `TABLE-SCAN` > `WHOLE-INDEX` since only record blocks are read

temp-table anomalies

- The first-alphabetical rule is replaced by a first-defined rule
- Fields cannot be marked as mandatory so uniqueness must be guaranteed by application code

fin