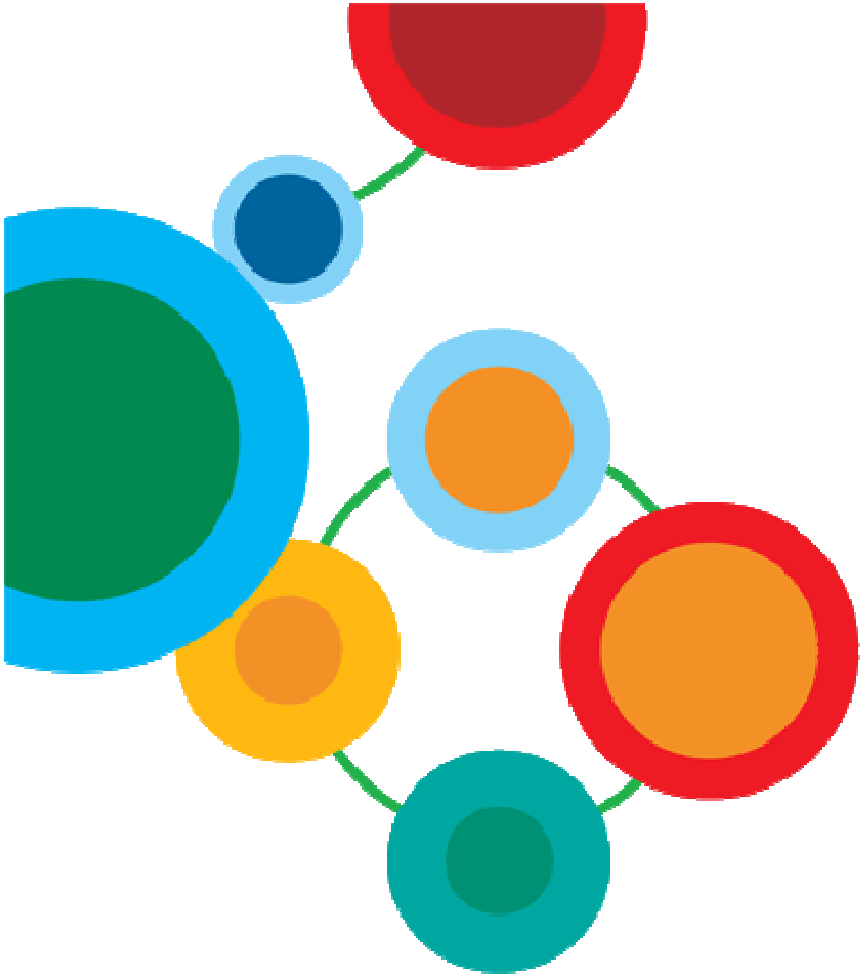

DB2 Developers' Guide to Optimum SQL Performance

Session Number 1708

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Outline

- Write efficient predicates
- Minimize SQL traffic
- Use multi-row operations
- Avoid sorting whenever possible
- Only touch columns and rows you need
- Literals vs. variables – know the difference
- Subqueries vs Joins
- OPTIMIZE FOR n ROWS
- +++

Traits of a well-performing SQL query

- Written in an efficient form
- Accurate statistics
- Optimal optimizer settings
- Adequate system resources

Query Optimization

SQL QUERY

```
SELECT N_NAME, COUNT(*)
  FROM ORDER, CUSTOMER, NATION
WHERE C_NATIONKEY = N_NATIONKEY
   AND C_CUSTKEY = O_CUSTKEY
   AND N_REGIONKEY = 4
   AND O_ORDERDATE BETWEEN ? AND ?
GROUP BY N_NAME;
```

Database Objects:

Tables
Indexes
Views
MQTs
...

Statistics:

# of rows in tables
# of distinct column values
...

Configuration:

Buffer pools
Sort pool
RID pool
...

Optimizer

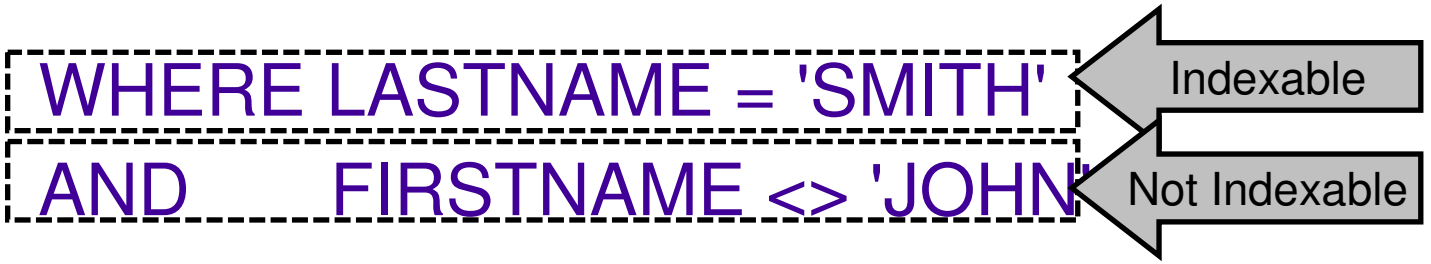
Predicates, predicates, predicates
... A prime influence on access paths

- Predicates
  - Found inside WHERE, ON, HAVING clauses
  - Have a huge impact on query performance!
- Can be:
  - Extremely filtering (qualify very few rows) = good!
  - Poorly filtering (qualify a ton of rows)

```
SELECT ... FROM EMP E, DEPT D
WHERE
  E.GENDER = 'F'                          -- Local pred  <-  -> equal
  AND E.AGE BETWEEN 25 AND 65             -- Local pred  <-  -> range
  AND E.DEPTID = D.DEPTID                 -- Join pred   <-  -> equal
  AND E.SAL = (SELECT MAX(SAL)            -- -> subquery
               FROM EMP WHERE ...)
  AND E.EDU IN ('BA, 'BS', 'MA', 'MS')    -- -> In list
```

Predicates: Indexable or Not?

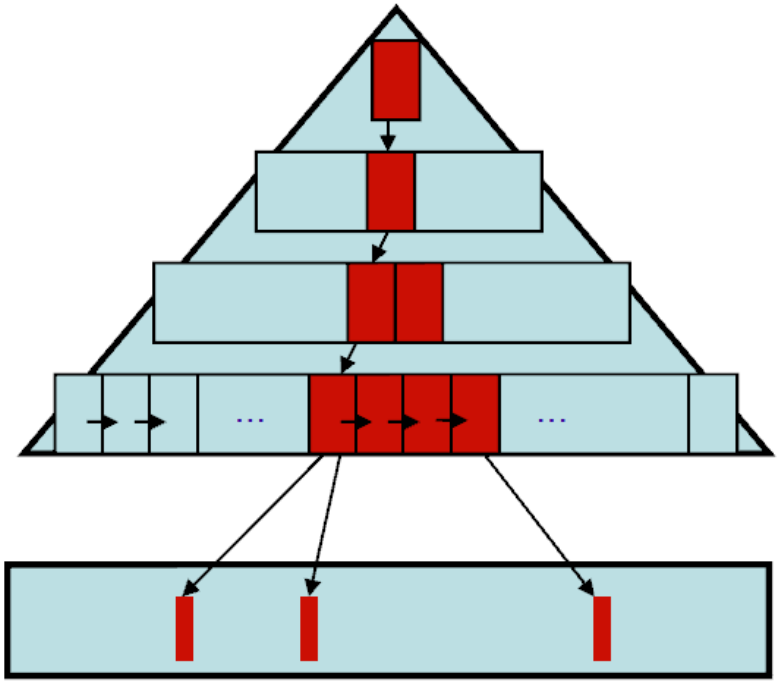
- Indexable Predicates
  - Can match index entries
  - May or may not become index matching predicates depending on available indexes and access path selected
  - The best kind of predicates
- Not Indexable Predicates
  - Cannot match index entries



Predicate Processing
Index Matching

- Restrict the range of data that is retrieved
  - Index Matching defines START and STOP keys on the index
- All other predicates will reject rows based upon this retrieved range of data

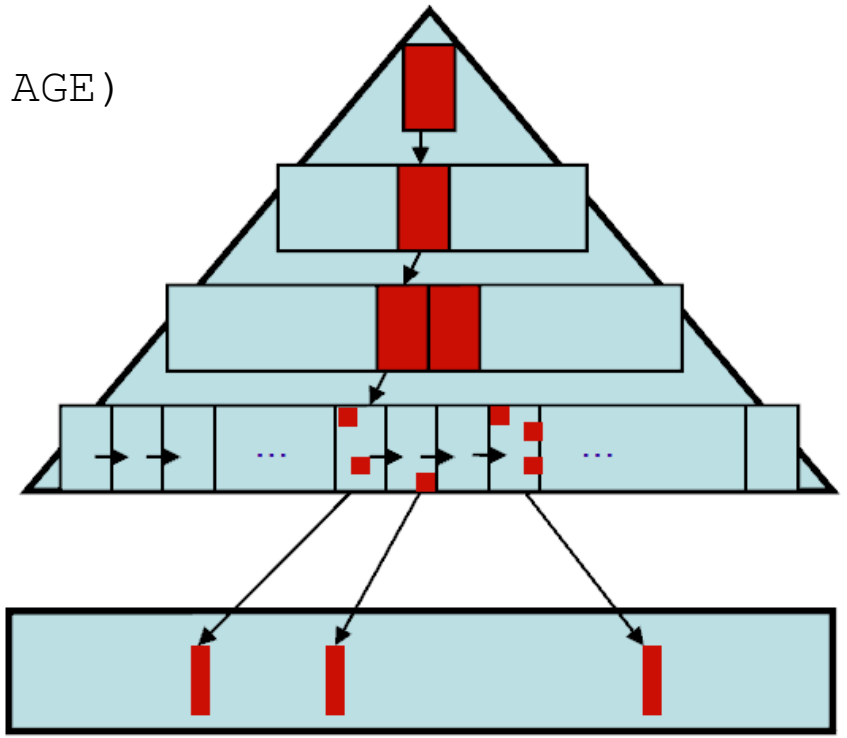
```
Index on EMPLOYEE(LASTNAME, FIRSTNAME, AGE)


SELECT COUNT(*)

FROM EMPLOYEES

WHERE LASTNAME = 'SPADE'
  AND FIRSTNAME = 'SAM'
  AND SALARY > ?
```



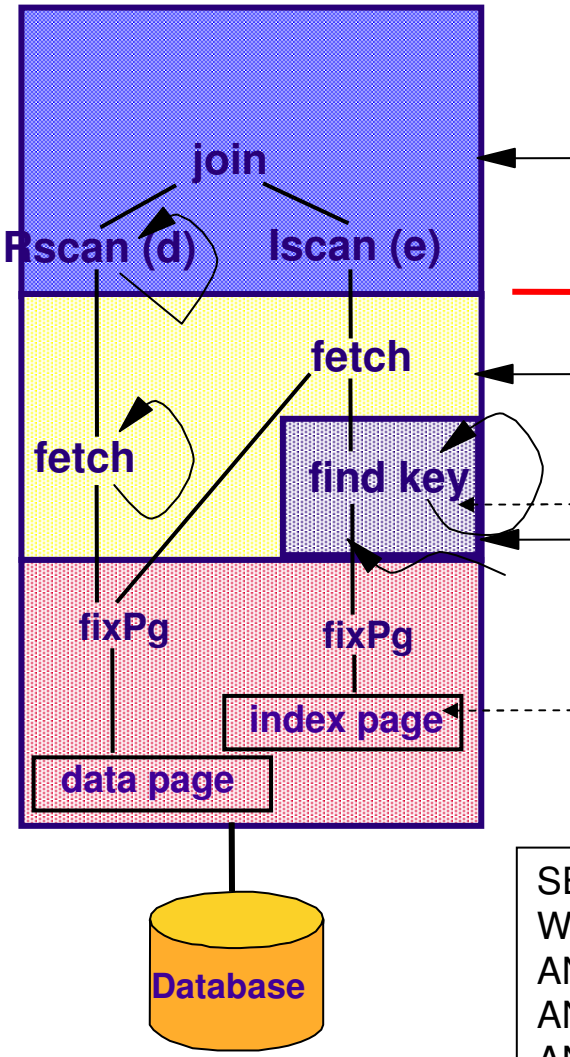
Predicate Processing
Index Screening

- Applied on the index after matching predicates, but before data access
- Column needs to exists in the chosen index
- Screening predicates do not limit the number of index entries read
- But can limit the number of data rows retrieved

```
Index on

EMPLOYEE(LASTNAME, FIRSTNAME, AGE)


SELECT COUNT(*)

FROM EMPLOYEES

WHERE LASTNAME = ‘SPADE’

AND SALARY > ?

   AND AGE > ?
```



Predicate Processing



Relational Data Service (RDS)

Data Manager

Index Manager

Residual Predicates

UPPER(PROJ) LIKE '%DEV%'

Others

GRADE <> 'X'

Index Screening

SAL > 125000

Index Matching

TYPE = 'ENGINEER'

Stage 2

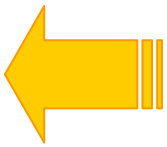
Stage 1

```
SELECT ... FROM EMP
WHERE TYPE = 'ENGINEER'
AND SAL > 125000
AND GRADE <> 'X'
AND UPPER(PROJ) LIKE '%DEV%'
```

Index on
(TYPE, DEPT, SAL)

Predicate Processing (contd.)

- Stage 1
  - Evaluated by the Data/Index Manager with relatively little expense
  - Some Stage 1 predicates are “Indexable” (i.e. use indexes)
- Stage 2
  - Much more expensive for DB2 to resolve due to additional processing and code path.
  - Cannot make effective use of indexes.
- What determines stage 1 vs stage 2?
  - Predicate syntax
  - Type and length of constants or columns in the predicate
  - Whether the predicate is applied before or after a join
  - Table join sequence
  - Read the official books for your particular release
- Well written queries
  - Filter as much as needed/possible within the query itself
  - Favor Stage 1 Indexable -> Stage 1 Others -> Stage 2



Promote predicates to earlier stage

- Watch out for functions or arithmetic against columns

Stage 2	Stage 1	Indexable
QTY * 2 = :hv		QTY = :hv / 2
YEAR(DCOL) = 2008		DCOL BETWEEN '2008-01-01' AND '2008-12-31'
:hv BETWEEN C1 AND C2		:hv >= C1 AND :hv <= C2
DCOL + 10 YEARS < CURRENT DATE		DCOL < CURRENT DATE - 10 YEARS
	DCOL <> '9999-12-31'	DCOL < '9999-12-31'
	GENDER <> 'F'	GENDER = 'M'

Minimize SQL traffic

- Don’t issue SQL if you can avoid it
  - E.g., Consider caching read-only constants on client
- Avoid generic “I/O boxes”
  - E.g., Consider customizing your SQL to suit your true need
- Avoid joins in applications
  - Let DB2 do what it does best

Avoid touching unnecessary data

- Only touch the columns you really need
- Extra columns can be a drag on performance
  - Access path may not be the best
    - E.g., INDEXONLY not available
  - Data is carried all the way from disk to the client
  - Increased CPU costs
- Avoid “SELECT *” unless really needed

Don’t return unnecessary rows

- Don’t filter rows in the application that DB2 can filter
  - Use predicates

- Consider FETCH FIRST n ROWS only
  - When the client will only see a limited # of rows
  - DB2 optimizes the access path accordingly
  - Can be used in subselects

```
SELECT PNAME, PCOST, SALARY
FROM PRODUCTS
ORDER BY PNAME
FETCH FIRST 20 ROWS ONLY
```

Minimize SQL traffic

Use Multi-row FETCH

- Returns up to 32,767 rows in a single API call
- Significant CPU performance improvements
- Works for static or dynamic SQL
- Works for scrollable or non-scrollable cursors
- Support for positioned UPDATEs and DELETEs
- Sample program DSNTEP4 = DSNTEP2 with multi-row fetch)

Minimize SQL traffic

Use Multi-row FETCH

- Coding multi-row fetch
  - “WITH ROWSET POSITIONING” on cursor declaration
  - “NEXT ROWSET” and “FOR n ROWS” on the FETCH
  - Define host variable arrays
  - Fetch loop to process the rows
- When using multi-row fetch
  - Avoid GET DIAGNOSTICS due to high CPU overhead
  - Use the SQLCODE field of the SQLCA
    - Fetch was successful (SQLCODE 000)
    - Fetch failed (negative SQLCODE)
    - End of file (SQLCODE 100)

Minimize SQL traffic

MERGE statement

Combine UPDATE and INSERT into a single statement via the SQL MERGE statement

```
MERGE INTO PRODUCT AS OLDPROD
USING (VALUES (:PID, :COST, :DISCOUNT)
       FOR :ROWCNT ROWS)
  AS NEWPROD(PID, COST, DISCOUNT)
ON OLDPROD.PID = NEWPROD.PID
WHEN MATCHED THEN
  UPDATE SET COST = NEWPROD.COST
           , DISCOUNT = NEWPROD.DISCOUNT
WHEN NOT MATCHED THEN
  INSERT (PID, COST, DISCOUNT)
  VALUES (NEWPROD.PID,
          NEWPROD.COST,
          NEWPROD.DISCOUNT)
```

Minimize SQL traffic

Select from Insert / Update / Delete

Benefits

- Select what was just changed
- Save multiple calls to DB2

Common Use Cases

- Identity columns or sequence values that get automatically assigned by DB2
- User-defined defaults and expressions that are not known to the developer
- Columns modified by triggers that can vary from insert to insert depending on values
- ROWIDs, CURRENT TIMESTAMP that are assigned automatically

Example:

```
/* Generate a unique id for the next customer */
SELECT CUSTID
FROM FINAL TABLE
  (INSERT INTO CUSTOMERS (CUSTID, CUSTNAME)
    VALUES
      (NEXT VALUE FOR CUSTSEQ, 'John Roberts'))
```

Avoid Unnecessary Sorts

- DB2 may perform a sort to support
  - ORDER BY
  - GROUP BY
  - Duplicate removal (DISTINCT, UNION, ...)
  - Join processing
  - Subquery processing
- But ...
  - Sorts can be expensive
  - An SQL statement may have multiple sorts
- Action items:
  - Examine DB2 explain information to check for sorts
  - Try to take advantage of ways in which DB2 can avoid a sort
  - If you must sort, only sort what's needed

Avoid Unnecessary Sorts (contd.)

ORDER BY

Index on (PTYPE, PNAME, PCOST)

- Matches all index columns

```
SELECT ...
FROM PROD
ORDER BY PTYPE, PNAME, PCOST
```

- Matching leading index column(s)

```
SELECT ...
FROM PROD
ORDER BY PTYPE
```

- Matching some index column(s), but others column(s) constrained

```
SELECT ...
FROM PROD
WHERE PTYPE = ‘X05’
ORDER BY PNAME
```

Avoid Unnecessary Sorts (contd.)

GROUP BY

Index on (PTYPE, PNAME, PCOST)

- Matches leading index columns

```
SELECT PTYPE, PNAME, COUNT(*)
FROM PROD
GROUP BY PTYPE, PNAME;
```

- Matching leading index column(s) but in different order

```
SELECT PNAME, PTYPE, AVG(SALARY)
FROM PROD
GROUP BY PNAME, PTYPE
// Watch out: results will not be in “GROUP BY order”
```

- Matching some index column(s), but others column(s) constrained

```
SELECT TYPE, COUNT(*)
FROM PROD
WHERE PTYPE = ‘X05’
GROUP BY PNAME;
```

Avoid Unnecessary Sorts (contd.)

DISTINCT

- DB2's DISTINCT processing has evolved
  - Prior to V9, DISTINCT usually involved a sort unless a unique index was available
    - GROUP BY could be used as a workaround
  - With DB2 9, DB2 may take better advantage of indexes

- Use DISTINCT only when needed
  - DISTINCT may involve expensive sorting
  - DISTINCTs inside subselects may involve materializations
  - Don't use DISTINCT just to be safe
    - Make sure duplicate rows are actually possible

Avoid Unnecessary Sorts (contd.)

DISTINCT

- If duplicates are to be removed:
  - Try rewriting the query using an IN or EXISTS subquery.
  - EXISTS is a faster alternative because DB2 can do “early out”

- Example

```
SELECT DISTINCT d.deptno, d.dname deptname
FROM dept d, emp e
WHERE d.deptno = e.deptno;
```

- Rewritten query

```
SELECT d.deptno, d.dname deptname
FROM dept d
WHERE EXISTS (SELECT 1 FROM emp e
              WHERE e.deptno = d.deptno);
```

OPTIMIZE FOR clause

- When # of rows needed is significantly < # of rows returned?
  - Tell the optimizer!
  - DB2 will try to eliminate “dams” such as “RID List Prefetch sort”

```
SELECT EMPNO, PNAME, DEPTNO, SALARY
FROM EMPLOYEE
WHERE DEPTNO > ?
OPTIMIZE FOR 14 ROWS
```

- This is not the same as ‘FETCH FIRST 14 ROWS ONLY’

Parameterize Dynamic SQL, unless, ...

```
SELECT ... FROM ORDERS WHERE CUSTID = 1331
SELECT ... FROM ORDERS WHERE CUSTID = 78
SELECT ... FROM ORDERS WHERE CUSTID = 3633
SELECT ... FROM ORDERS WHERE CUSTID = 26631
SELECT ... FROM ORDERS WHERE CUSTID = 12
...
```

VS.

```
SELECT ... FROM ORDERS WHERE CUSTID = ?
```

Parameterize Dynamic SQL, unless, ...

- Embedded Literals
  - + Optimizer can produce best access path a specific value
  - + Useful when you want to beat skew
    - - But you need the right frequency/histogram stats
  - - Dynamic SQL cache may not be effectively used
    - + V10 Statement Concentration can help
- Markers or Host Variables
  - + For dynamic SQL, full dynamic SQL cache exploitation
  - - Suboptimal access paths for skewed data
    - - What if ‘M’ = 1%, ‘F’ = 99%?
  - + REOPT(ONCE / AUTO / ALWAYS) can help

Think joins before subqueries

- Joins
  - Allow DB2 to pick the best table access sequence
  - Can outperform subqueries
- Subqueries
  - Force a specific sequence onto DB2

- Think of joining as a first resort, and subquerying as a last resort.

- DB2 can rewrite some subqueries -> joins

Think joins before subqueries (contd.)

```
Unique index on (DIVISION, DEPTNO)
```

Original query:

```
SELECT ... FROM EMP
WHERE DEPTNO IN
   (SELECT DEPTNO FROM DEPT
    WHERE LOCATION IN ('SAN JOSE', 'SAN FRANCISCO')
      AND DIVISION = 'MARKETING');
```

Rewritten query:

```
SELECT ... FROM EMP, DEPT
WHERE EMP.DEPTNO = DEPT.DEPTNO
  AND DEPT.LOCATION IN ('SAN JOSE', 'SAN FRANCISCO')
  AND DEPT.DIVISION = 'MARKETING';
```

Subqueries
Correlated vs Non-Correlated

```
SELECT * FROM EMP X
   WHERE  JOB = 'DESIGNER'
      AND  EXISTS (SELECT 1
                   FROM   PROJ
                   WHERE  DEPTNO = X.WORKDEPT
                      AND  MAJPROJ = 'MA2100');
```

Correlated

Performed for each outer query

```
SELECT * FROM EMP
  WHERE  JOB = 'DESIGNER'
    AND  WORKDEPT IN (SELECT DEPTNO
                      FROM   PROJ
                      WHERE  MAJPROJ = 'MA2100');
```

Non-Correlated

Processed upfront

Subqueries: To correlate or not?
Answer: It depends!

```
SELECT EMPID, EDLEVEL
FROM EMP E
WHERE
    JOBTYPE = ?
AND EDLEVEL >=
 (SELECT AVG(EDLEVEL)
  FROM EMP
  WHERE DEPTID = E.DEPTID)
```

Average computed for each employee's department, over and over again

Works best for few employees selected.

```
SELECT EMPID, NAME, EDLEVEL
FROM EMP E,
    (SELECT DEPTID,
     AVG(EDLEVEL) AVGED
     FROM EMP
     GROUP BY DEPTID) A
WHERE
    JOBTYPE = ?
AND E.DEPTID = A.DEPTID
AND EDLEVEL >= AVGED
```

Average-per-department, computed once for all departments

Works best when many employees selected.

Subquery evaluation order

- Non-correlated subqueries are executed before correlated
  - Multiple non-correlated subqueries are executed in the sequence they are coded
- Next are correlated subqueries
  - Multiple correlated subqueries are executed in the sequence they are coded
  - Correlated subqueries cannot be executed however until all correlation predicates are available
- Code subqueries in order of restrictiveness

Order of Subquery Predicate Evaluation

```
WHERE NOT EXISTS
(SELECT 1 FROM DSN8710.PROJ P1
 WHERE P1.RESPEMP = E.EMPNO)
AND NOT EXISTS
(SELECT 1 FROM DSN8710.PROJ P2
 WHERE P2.DEPTNO = E.WORKDEPT)
```

42 executions
25 rows qualify

25 executions
4 rows qualify

Reverse the subqueries

42 executions
5 rows qualify

5 executions
4 rows qualify

```
WHERE NOT EXISTS
(SELECT 1 FROM DSN8710.PROJ P2
 WHERE P2.DEPTNO = E.WORKDEPT)
AND NOT EXISTS
(SELECT 1 FROM DSN8710.PROJ P1
 WHERE P1.RESPEMP = E.EMPNO)
```

What did we discuss?

- Write efficient predicates
- Minimize SQL traffic
- Use multi-row operations
- Avoid sorting whenever possible
- Only touch columns and rows you need
- Literals vs. variables – know the difference
- Subqueries vs Joins
- OPTIMIZE FOR n ROWS
- +++

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