1: It computes a relation with only a column for CITY where each tuple represents the city of a supplier that sells a red colored part which costs over $100.

2: $T_1 \leftarrow (\text{PARTS}) * (\text{CATALOG})$
RESULT $\leftarrow \pi_{\text{PNAME}}(T_1)$

3: $T_1 \leftarrow \pi_{\text{SID}}(\sigma_{\text{STREET = '1 Central Ave'}}(\text{SUPPLIERS}))$
$T_2 \leftarrow (\text{CATALOG}) * (T_1)$
$T_3 \leftarrow (\text{PARTS}) * (T_2)$
RESULT $\leftarrow \pi_{\text{PNAME}}(T_3)$

4: $T_1 \leftarrow \pi_{\text{PID}}(\sigma_{\text{COLOR = 'red'}}(\text{PART}))$
$T_2 \leftarrow (\text{CATALOG}) * (T_1)$
$T_3 \leftarrow (\text{SUPPLIERS}) * (T_2)$
RESULT $\leftarrow \pi_{\text{SNAME}}(T_3)$

5: $T_1 \leftarrow \pi_{\text{PID}}(\sigma_{\text{COLOR = 'red' OR COLOR = 'green'}}(\text{PARTS}))$
$T_2 \leftarrow (\text{CATALOG}) * (T_1)$
RESULT $\leftarrow \pi_{\text{SID}}(T_2)$

6: $T_1 \leftarrow \pi_{\text{PID}}(\sigma_{\text{COLOR = 'red'}}(\text{PARTS}))$
$T_2 \leftarrow (\text{CATALOG}) * (T_1)$
$T_4 \leftarrow \pi_{\text{SID}}(T_2)$
$T_5 \leftarrow \pi_{\text{SID}}(\sigma_{\text{STREET = '221 Parker Street'}}(\text{SUPPLIERS}))$
RESULT $\leftarrow (T_4) \cup (T_5)$

7: $T_1 \leftarrow \pi_{\text{PID}}(\sigma_{\text{COLOR = 'red'}}(\text{PARTS}))$
$T_2 \leftarrow (\text{CATALOG}) * (T_1)$
$T_3 \leftarrow \pi_{\text{SID}}(T_2)$
$T_4 \leftarrow \pi_{\text{PID}}(\sigma_{\text{COLOR = 'green'}}(\text{PARTS}))$
$T_5 \leftarrow \pi_{\text{SID}}((\text{CATALOG}) * (T_4))$
RESULT $\leftarrow (T_3) \cap (T_5)$

8: $T_1 \leftarrow \pi_{\text{SID}}(\sigma_{\text{CITY = 'Newark'}}(\text{SUPPLIERS}))$
$T_2 \leftarrow \pi_{\text{PID}}((\text{CATALOG}) * (T_1))$
$T_3 \leftarrow \pi_{\text{PID}}(\sigma_{\text{COLOR = 'red'}}(\text{PARTS}))$
RESULT $\leftarrow (T_2) \cup (T_3)$

9: $T_1 \leftarrow \pi_{\text{SID}}(\sigma_{\text{CITY = 'Newark'}}(\text{SUPPLIERS}))$
$T_2 \leftarrow (\text{CATALOG}) * (T_1)$
$T_3 \leftarrow \pi_{\text{PID}}(T_2)$
$T_4 \leftarrow \pi_{\text{SID}}(\sigma_{\text{CITY = 'Trenton'}}(\text{SUPPLIERS}))$
$T_5 \leftarrow \pi_{\text{PID}}((\text{CATALOG}) * (T_4))$
RESULT $\leftarrow (T_3) \cap (T_5)$

10: $T_1 \leftarrow \pi_{\text{SID}}(\text{SUPPLIERS})$
$\text{RESULT} \leftarrow \pi_{\text{PID}}((\text{CATALOG}) \div (T_1))$

11: $T_1 \leftarrow \pi_{\text{SID}}(\text{CATALOG})$
$\text{RESULT} \leftarrow \pi_{\text{PID}}((\text{CATALOG}) \div (T_1))$

12: $T_1 \leftarrow \pi_{\text{SID}}(\sigma_{\text{CITY = 'Newark' OR CITY = 'Trenton'}}(\text{SUPPLIERS}))$
$\text{RESULT} \leftarrow \pi_{\text{PID}}((\text{CATALOG}) \div (T_1))$

Equivalently, for PIDs for every supplier who is at Newark and every supplier who is at Trenton.

$T_1 \leftarrow \pi_{\text{SID}}(\sigma_{\text{CITY = 'Newark'}}(\text{SUPPLIERS}))$
$T_2 \leftarrow \pi_{\text{PID}}((\text{CATALOG}) \div (T_1))$
$T_3 \leftarrow \pi_{\text{SID}}(\sigma_{\text{CITY = 'Trenton'}}(\text{SUPPLIERS}))$
$T_4 \leftarrow \pi_{\text{PID}}((\text{CATALOG}) \div (T_3))$
$\text{RESULT} \leftarrow (T_2) \cap (T_4)$

13: $T_1 \leftarrow \pi_{\text{SID}}(\sigma_{\text{CITY = 'Newark'}}(\text{SUPPLIERS}))$
$T_2 \leftarrow \pi_{\text{PID}}((\text{CATALOG}) \div (T_1))$
$T_3 \leftarrow \pi_{\text{SID}}(\sigma_{\text{CITY = 'Trenton'}}(\text{SUPPLIERS}))$
$T_4 \leftarrow \pi_{\text{PID}}((\text{CATALOG}) \div (T_3))$
$\text{RESULT} \leftarrow (T_2) \cup (T_4)$

14: Tuples in the output of the division operation will have PID and COST as columns, which need to be present for all values of SID over CATALOG. 12 is more restrictive because we divide CATALOG by a larger number of SID tuples as a result of CITY = 'Newark' or CITY = 'Trenton'. In 13, SIDs for each city are considered, thereby performing division over a smaller number of tuples. Then, the union of these operations is considered as the result.

15: $\text{R(SID, PID1, COST1)} \leftarrow \pi_{\text{SID,PID,COST}}(\text{CATALOG})$
$S\,(\text{SID, PID2, COST2}) \leftarrow \pi_{\text{SID,PID,COST}}(\text{CATALOG})$
$T_1 \leftarrow R \bowtie_{\text{(R.SID = S.SID) AND (R.COST1) > S.COST2}} S$
$\text{RESULT} \leftarrow \pi_{\text{PID1,PID2}}(T_1)$

16: $\text{R(SID, PID1, COST1)} \leftarrow \pi_{\text{SID,PID,COST}}(\text{CATALOG})$
$S\,(\text{SID, PID2, COST2}) \leftarrow \pi_{\text{SID,PID,COST}}(\text{CATALOG})$
$T_1 \leftarrow R \bowtie_{(R.\text{SID}=S.\text{SID}) \text{ AND } (\text{NOT}(R.\text{PID1}=S.\text{PID2}))} S$
$\text{RESULT} \leftarrow \pi_{\text{SID}}(T_1)$

17: $T_1 \leftarrow \pi_{\text{SID,PID}}(\text{CATALOG})$
$T_2 \leftarrow {}_{\text{SID}}\mathscr{F}_{\text{COUNT PID}}(T_1)$
$\text{RESULT} \leftarrow \pi_{\text{SID}}(\sigma_{\text{Count\_pid} \geq 2}(T_2)$

18: $T_1 \leftarrow \sigma_{\text{CITY = 'Newark'}}(\text{SUPPLIERS})$
$T_2 \leftarrow (\text{CATALOG}) * (T_1)$
$T_3 \leftarrow {}_{\text{PID, SID}}\mathscr{F}_{\text{MAXIMUM COST}}(T_2))$
$T_4 \leftarrow (T_3) * (T_2)$
$\text{RESULT} \leftarrow \pi_{\text{PID,SID,SNAME}}(T_4)$

19: $T_1 \leftarrow \pi_{\text{PID,PNAME}}(\text{PARTS})$
$T_2 \leftarrow (\text{CATALOG}) * (T_1)$
$\text{RESULT} \leftarrow {}_{\text{PID,PNAME}}\mathscr{F}_{\text{COUNT SID}}(T_2)$

20: $T_1 \leftarrow \pi_{\text{PID,PNAME}}(\text{PARTS})$
$T_2 \leftarrow (\text{CATALOG}) * (T_1)$
$\text{RESULT} \leftarrow {}_{\text{PID,PNAME}}\mathscr{F}_{\text{AVERAGE COST}}(T_2)$

21: $T_1 \leftarrow \pi_{\text{PID}}(\sigma_{\text{COLOR = 'red'}}(\text{PARTS})$
$T_2 \leftarrow (\text{CATALOG}) * (T_1)$
$\text{RESULT} \leftarrow \mathscr{F}_{\text{AVERAGE COST}}(T_2)$

22: $T_1 \leftarrow \pi_{\text{SID}}(\sigma_{\text{SNAME = 'Yosemite Sham'}}(\text{SUPPLIERS}))$
$T_2 \leftarrow (T_1) * (\text{CATALOG})$
$\text{RESULT} \leftarrow \mathscr{F}_{\text{AVERAGE COST}}(T_2)$