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COLUMBUS PROJECT

MIRROR BLANK 8.4 mt diam F/1.14

PRELIMINARY AND CONCEPTUAL DESIGN OF AN AUTOMATIC PROCEDURE FOR MIRROR STRESS CHECKS

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1. INTRODUCTION

In this report we want state some preliminary considerations, about the possibility of to design and to carry out an Automatic Procedure for Mirror Stress Check (**APMSC**), in order to verify the stresses in the mirror blank.
There is a twofold need of such a procedure:

- during **design** phase, in order to check gravity effects at different elevation angles, or to combine gravity effects with thermal ones, or better in order to check the big number of load conditions produced, for example, by different possible aberration corrections.
  In this way it will be possible to state some ranges for allowable mirror corrections.
  In fact it is impossible to state an allowable range for a single corrector force, independently from the values of all the other applied loads.
  This means that, during design phase, it is necessary to consider an big number of load combinations in order to controle if some force ranges are allowable.
  The usefulness of an automatic check procedure is evident.

- During **operative conditions,** when the real aberrations will be known and, if they haven't been checked in design phase, it will be necessary to check stresses produced by corrector forces; or when there will be the need to verify new loadings (thermal, or due new handling schemes etc.).

Anycase this report is only a preliminary conceptual design of APMSC, the purpose is only to introduce and to provoke a discussion about the main features and the tools that can be used in order to carry out such a procedure.

2. APMSC GOALS

The main requirements of the APMSC are:

1) To allow global and local stress checks at each elevation angle, for a priori defined loading conditions as gravity, forces exerted by axial supports, forces exerted by lateral supports, thermal loadings, supporting schemes during handling, and their combinations.
   In order to fulfill this first goal, APMSC needs a data bank where proper information are stored.
2) To allow to update the data bank, in order to analyze new loading conditions.
   In order to fulfill this goal APMSC needs the FE model of the mirror, a FE code and a proper interface between the FE output and the data bank.

Moreover we want also appoint a procedure that, for some loading conditions often used, allows to quickly state if a loading is safe; this goal is obtained minimizing the amount of cheks, by means of previously stored verifications.

3. APMSC STRUCTURE

In the following paragraph we describe the main sections that form APMSC.
We distinguish these sections between **data banks** and **operative** ones.
In data banks the information are stored, while operative sections perform some operations on these information in order to satisfy the user requests.
In the flow charts enclosed at the end of this report, data banks and operative sections are showed by the following symbols:

3.1. DATA BANKS

We need the following data banks:

- **Stress Data Bank (SDB)** where, for all the finite elements of the numerical model and for each **Elementary Loadings (EL),** the stresses are stored.
  N.B. in this sections we means as **elementary loading,** a loading related to only one supporting forces (axial or lateral), or due to gravity, or to a stated temperature distribution etc.

  If:
  n_{ef} = finite element number
  n_{EL} = elementary loading number
  n_S = stress components for each finite element

  $$\left[SDB\right] = n_{EL} \times n_{ef} \times n_S$$

- **Stress Index Data Bank (SIDB)** where, for all the finite elements of the whole mirror, and for all the **Elementary Loading Combinations (ELC),** the stress indexes

$\gamma_{i,j} \quad \left[i=1,n_{fe} \quad j=1,n_{EC}\right]$

are stored.

Where:
n_{EC} = elementary loading combination number

$\left[SIDB\right] = n_{EC} \times n_{ef}$

We means as **stress index,** the ratio between maximum tensile stress in each finite element (computed taking into account global and local peak stresses) and allowable stress. So, if in the *jth* elementary combination the allowable stress isn't exceeded, it will be $\gamma_{i,j} < 1; \quad i=1,n_{fe}$.
We can also define the stress index of the whole mirror $\gamma_{whole,j}$, for the *jth* elementary loading combination as:
$\gamma_{whole,j} = \max \{\gamma_{i,j}; \quad i=1,n_{fe}\}$

We means as **Elementary Loading Combinations (ELC),** a combination of forces applied at all the supports that is particular meaningfull. The importance of those elementary combinations is due to the fact that we suppose that the APMSC user will be often interested to check loadings that are obtainable as linear combination of these ELC. For example, each elementary combination could be the set of axial forces that allow to correct a particular aberrations.

- **Geometry Data Bank (GDB)**
  In order to perform stress verifications and to produce main stress plots it is necessary, for each element, to store: incidences, node coordinates, thickness (referred to operative conditions), local reference systems.

- **Check Rules Data Bank (CRDB)** In this section, for each element of the FE model, are stored the rules that allow to estimate local stress peaks from the global stress pattern. These rules contain the effects due to:
  - local stress diffusion, in the elements where forces are directly applied,
  - lateral force offset,
  - geometrical singularities, as for example:
    ventilation holes in the back plate
    crosspin holes in the ribs
    upper plate overhang

- **Finite Element Mirror Model (FEMM).** We think that it is convenient to use a FE model of one quarter of the mirror. Then, using symmetry and asymmetry rules it is possible to analyze a lot of real conditions on the whole mirror. Moreover, modelling only one mirror quarter, it is possible to carry out more refined numerical models and to have a better description of internal stresses.

3.2. OPERATIVE SECTIONS

As previously explained we name operative the sections that perform some operations using information stored in data banks.
The operative sections in APMSC are:

- **Input Section (IS)** It is the interface with the user, essentially it defines the kind of analysis required by the user.

- **Finite Element Code (FEC).** Every reliable, general purpose, linear, FE structural code may be used.

- The interface between FEC output and data banks is the **Updating Data Banks (UDB)** section.
  It reads the FEC output and it proceed to the formatting of the information necessary to update SDB and SIDB, introducing new loadings, in terms of stresses in SDB, in terms of stress index in SIDB (computed by CCS, see next section).

- The **Complete Check Section** (CCS) is the section that using:
  - stresses stored in SDB
  - geometry stored in GDB
  - rules stored in CRDB
  - combination coefficients (in terms of EL)

  performs all stress checks (global stress and local peaks), for all the mirror elements, or for a stated part of them.
  It computes also the stress indeces γ_i for all the elements and the stress index of the whole mirror:

$$\gamma_{whole} = \max\left\{\gamma_i\right\} \qquad i=1,n_{fe}$$

- **First Fast Coarse Check (FFCC)**
  It is the simplest and coarsest check level foreseen in APMSC, but it is also very fast.
  It is possible to apply it only if the loading that must be checked is obtainable as combination of ELC.
  if:
  c_j (j=1,n_{EC}) are the coefficients of the combination
  $\gamma_{whole,j}$ (j=1,n_{EC}) are the stress indeces of the whole mirror

  FFCC perform the following check:

  $$\sum_{1\ j}^{n_{EC}} c_j\ \gamma_{whole,j} < 1$$

  If that is verified the loading is allowable. (All checks must be performed for different elevation angles, in a range specified by the user).

  FFCC is very fast since it requires only few multiplications; on the other hand FFCC is very coarse, in fact to sum the $\gamma_{whole,j}$ of all the ELC means to accept the wrong (but safe) hypoteses that all the ELC produce maximum main stresses in the same location (finite element), with the same direction and sign.

- **Second Fast Coarse Check (SFCC)**
  As FFCC also SFCC is possible only if the loading that must be checked is obtainable as combination of ELC.
  APMSC try this check only if FFCC isn't verified.

  In SFCC it is loosen the heavy hypotesis that all the ELC produce maximum main stresses in the same finite element, but it is kept the simplifying hypotesis that in each element all the ELC produce main stresses having the same direction and sign.

  SFCC, for each finite element, perform the following check:

  $$\sum_{1\ j}^{n_{EC}} c_j\ \gamma_{i,j} < 1 \qquad (i=1,n_{ef})$$

  If that is verified for all the finite elements the loading is allowable.

- **Third Fast Coarse Check (TFCC)**
  As FFCC and SFCC also TFCC is possible only if the loading that must be checked is obtainable as combination of ELC.
  APMSC try this check only when FFCC and SFCC aren't verified.

  TFCC perform the following operations:

- it receives from SFCC the list of non-verified elements,
- it computes the loading that must be checked as combination of EL (initially it was ELC combination).
- it transmit previous data to CCS in order to perform the complete stress checks for the element set that was not verified in SFCC

- The **Output Section (OS)** gives to the user the following information:
  - check criteria used: FFCC, SFCC, TFCC or CCS
  - main results of the checks, as for example:
    stress index of the whole mirror, or an upper bound of the stress index if fast check criteria have been used, the EL or the ELC giving the maximum contribute to the stress index, check rule giving maximum contribute to the stress index etc.
  - main stress plots

Before to go on with APMSC description we want to point out some concepts related to the different verification kinds previously introduced (FFCC, SFCC, TFCC and CCS).
As explained we introduced different levels in the checks.
Different levels are related:

1) to the possibility to express the loading that must be verified as combination of ELC. In this case is possible to use CCS or FFCC + SFCC + TFCC. Otherwise CCS must be used.
2) to the amount of checks that APMSC perform (directly related to the time that it needs in order to run). The amount of operations performed increases considerably passing from FFCC, to SFCC, to TFCC and finally to CCS.
   FFCC and SFCC use stress indeces stored in SIDB and don't perform new stress cheks.
   TFCC performs stress checks only for the elements that don't satisfy SFCC.
   CCS perform all stress checks.

If the user don't require the complete stress cheks and the loading that must be verified is a combination of ELC, APMSC can try the FFCC, or the SFCC, or the TFCC and it stops to the first one that is satisfied, saving time.

4. APMSC USE

It is possible to foresee the following APMSC uses:

4.1. DATA BANK REVISION

It is the case when new loading conditions must be added to the data banks.
The flow chart of this procedure is reported in figure 1.

The new loadings are introduced in FEMM, then UDB reads FEC output and updates SDB, if SIDB too must be updated, UDB transmits stresses to CCS that computes stress indeces and finally stores them in SIDB.

4.2. VERIFICATION PROBLEM

If data bank contain all EL or ELC necessary to define the loading that must be verified we can proceed to the verifications.
The flow chart of such a procedure is reported in figure 2-3.

We have essentially two possible runs:

1) If the loading that must be verified can be obtained only as EL combination, or if the user wants to check all the elements (complete verification), the procedure, after IS, goes to CCS that perform stress checks of all the elements and then it passes to OS (figure 2).
   It is the run more time expensive, but it allows to compute "exactly" the stress index of the whole mirror for the loading considered.
2) If the loading that must be verified can be obtained as ELC combination and the user wants only to know if it is allowable, using an "overall check", the procedure goes to FFCC,SFCC and TFCC and it stops to the first that gives positive results, passing to OS (figure 3)
   It is the faster run, the speed depends on the level giving positive results, but it computes only an upper bound of the stress index of the whole mirror for the loading considered.

Finally in figure 4 are pointed out the data banks where are stored the information used by the main operative sections.

5. FINAL REMARKS

Finally we want to point out the importance of a complete transparency of the operation performed by APMSC.
APMSC will use a predetermined set of rules for the checks, it is the user that must judge if they are correct for the particular problem that it is solving. So it is necessary to give to the user all the tools in order to know the check rules used and in order to controle if their are correct for the particular problem.
Also the stress values, not only the results of the checks, must be available to the user with some facilities (for example maximum stresses), in the case he would apply new check rule.
In fact we think that the best use of an automatic procedure is to don't use it "automatically".
The traspanrency will be obtained by means of an exhaustive manual and by means of different output levels each of them giving information.

Previous considerations are only a preliminar proposal about the problem in object. Further discussions, involving designers and telescope users, are necessary in order to better define APMSC features.

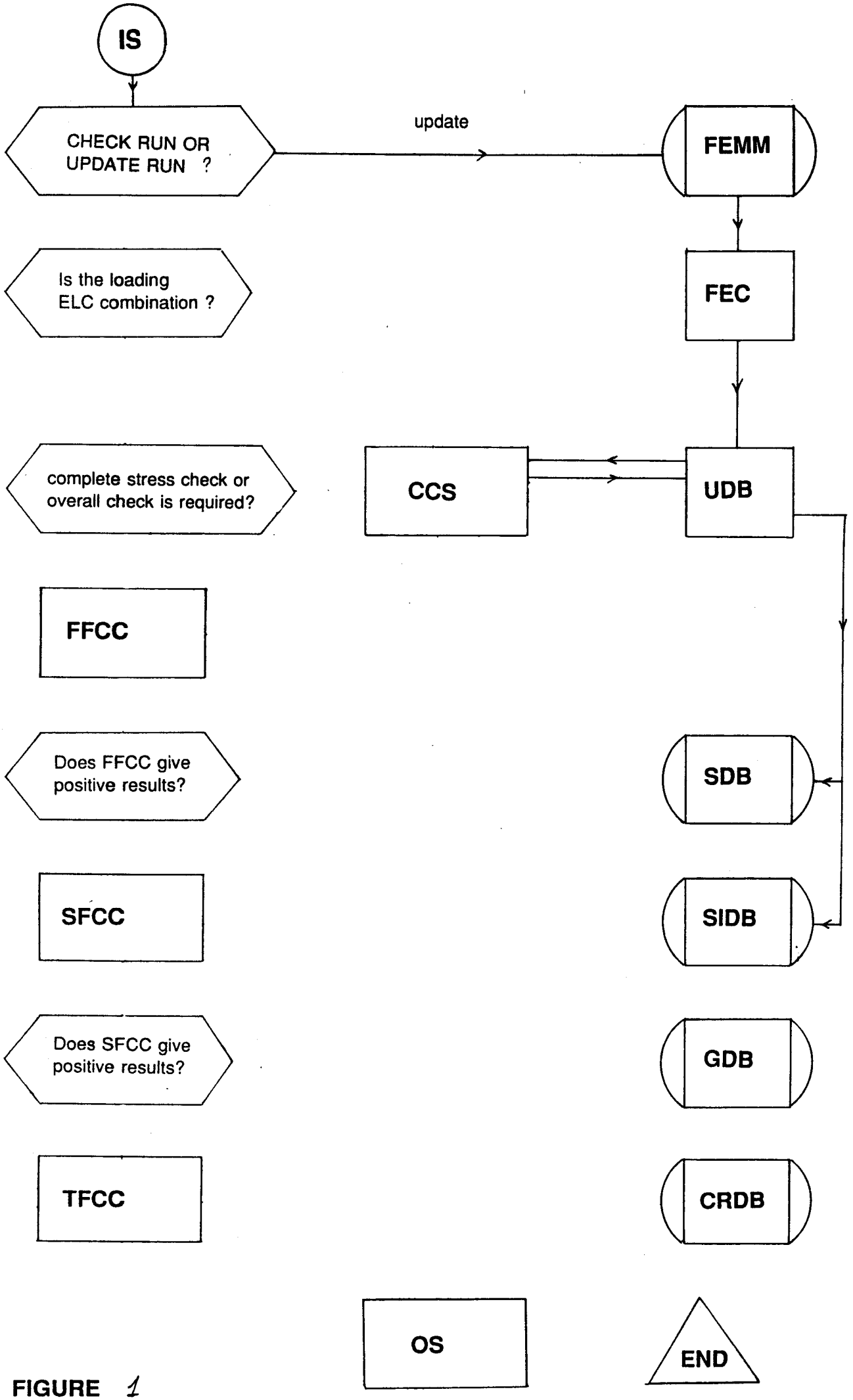
IS
CHECK RUN OR UPDATE RUN ?
update
FEMM
Is the loading ELC combination ?
FEC
complete stress check or overall check is required?
CCS
UDB
FFCC
Does FFCC give positive results?
SDB
SFCC
SIDB
Does SFCC give positive results?
GDB
TFCC
CRDB
OS
END

FIGURE 1

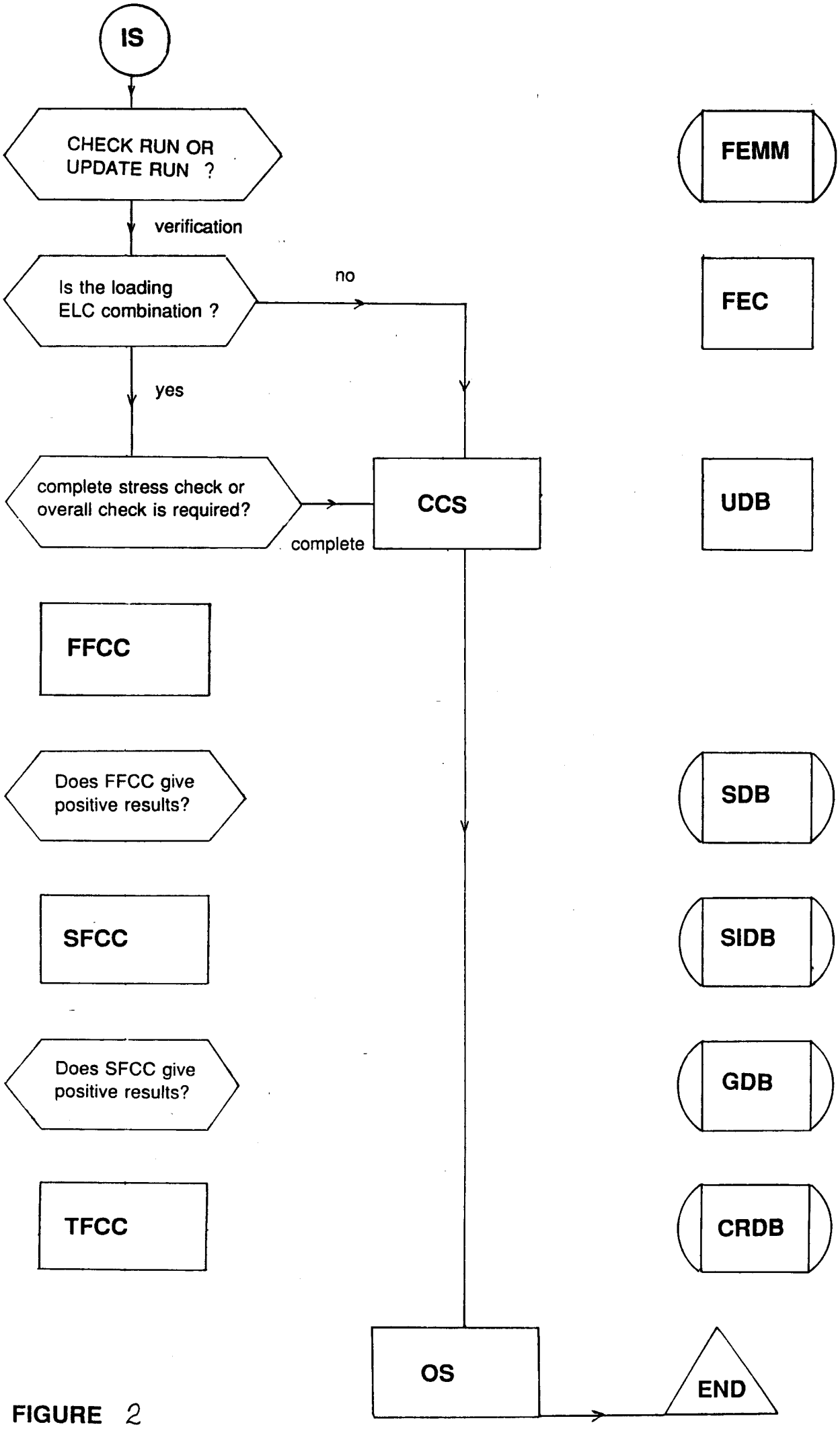
IS
CHECK RUN OR UPDATE RUN ?
verification
Is the loading ELC combination ?
no
yes
complete stress check or overall check is required?
complete
CCS
FFCC
Does FFCC give positive results?
SFCC
Does SFCC give positive results?
TFCC
OS
END
FEMM
FEC
UDB
SDB
SIDB
GDB
CRDB

FIGURE 2

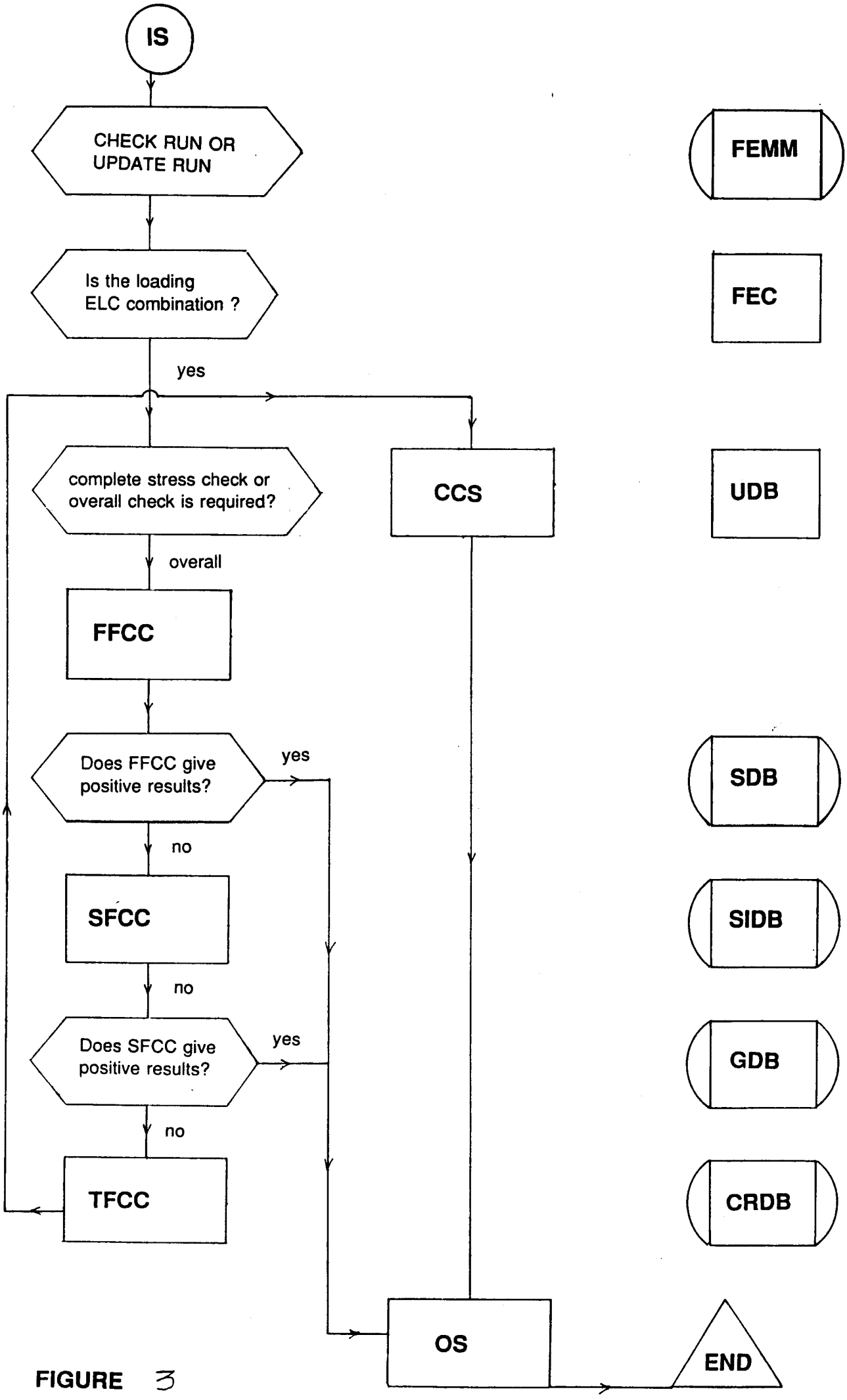
IS
CHECK RUN OR UPDATE RUN
Is the loading ELC combination ?
yes
complete stress check or overall check is required?
overall
FFCC
Does FFCC give positive results?
yes
no
SFCC
no
Does SFCC give positive results?
yes
no
TFCC
CCS
OS
END
FEMM
FEC
UDB
SDB
SIDB
GDB
CRDB

FIGURE 3

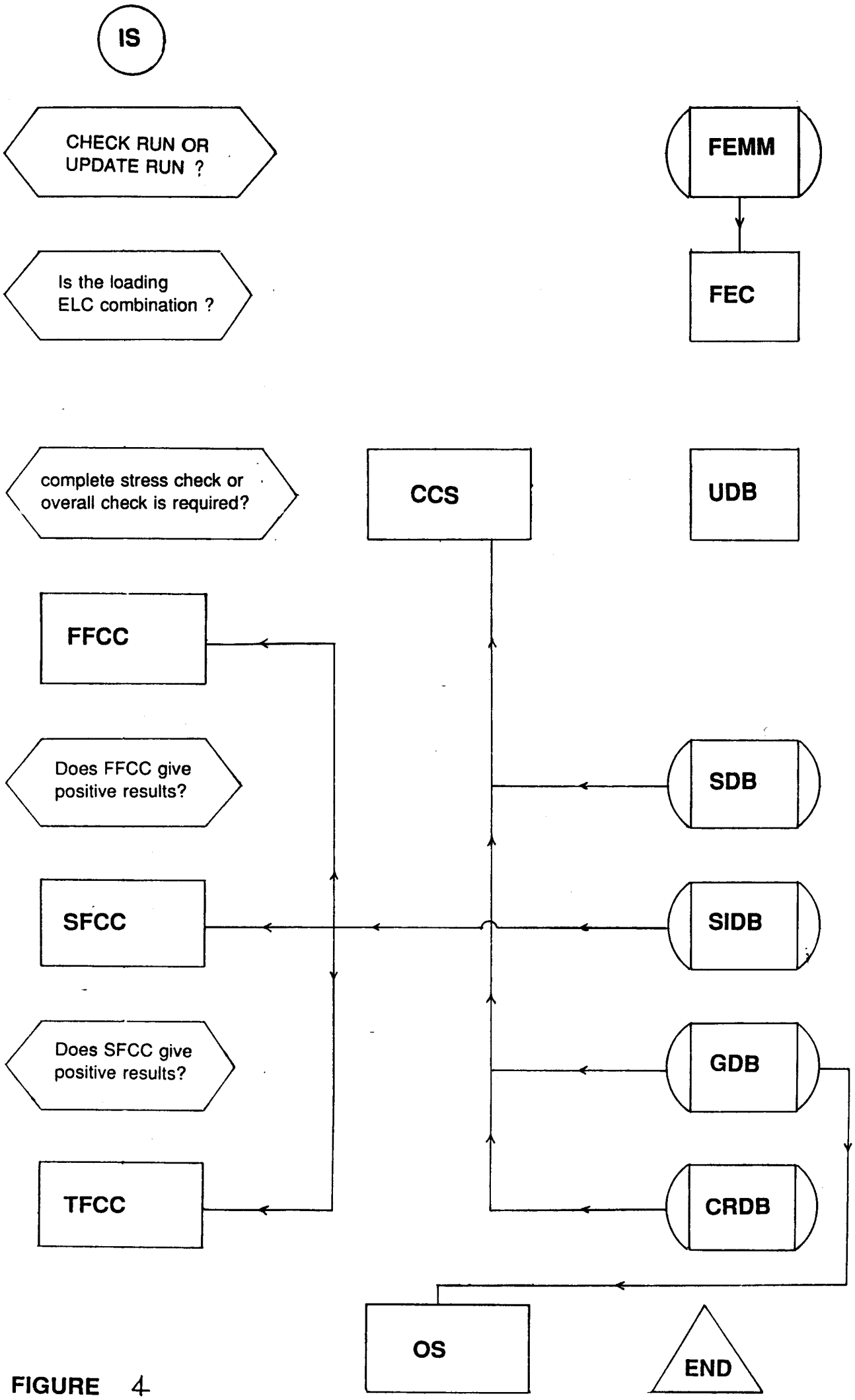
IS
CHECK RUN OR UPDATE RUN ?
FEMM
Is the loading ELC combination ?
FEC
complete stress check or overall check is required?
CCS
UDB
FFCC
Does FFCC give positive results?
SDB
SFCC
SIDB
Does SFCC give positive results?
GDB
TFCC
CRDB
OS
END

FIGURE 4