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# Automation of MCDOR at NMT-3
## Los Alamos National Laboratory

Final Report Prepared For LANL, NMT-3 Technical Staff :

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by


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**LANL-NMT'3 Technical Staff**

## SUMMARY


This report describes research and development activities conducted by the author in collaboration with LANL-NMT3 Technical Staff, on stepwise automation of LANL-NMT-3's Multiple-Cycle Oxide Reduction (MCDOR) manufacturing line, during a two year period from 9/1/91 through 3/31/93. These activities may be grouped into 4 different categories as listed below :

1- Research, development, conceptualization, design and fabrication of an automation set up to automatically weigh powders, of different particle size and shape distributions, using an electronic balance such that the electronic balance to within an


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accuracy of (gm) may be reprogrammable for specific weight set points. Thus, when a set point in weight is reached or by means of a vibratory feeder feeding a multiple–pan container (Inverted Bicycle Seat, IBS), on the electronic balance, the electronic balance will send an electronic signal out to switch off the vibratory feeder.

2– Research, development, conceptualization, design and fabrication of an automation set up to automatically transport the mixture of powders in part 1 to a feeding location (station) where they will be added to the molten solvent inside the furnace.

3– Integration of systems in 1 and 2 above.

4– Research, development, conceptualization, design and fabrication of a levitation (suspension) system for the automatic weighing station in part 1.

The above goals were all achieved during the research and development period and the completed system and the associated hardware and software were delivered to LANL–NMT3 by April 1993. Additional research and development work is recommend to further automatic and integrate the developed system with the MCDOR furnace system.

## INTRODUCTION

The automation of various parts of multiple–cycle direct oxide reduction (MCDOR) at LANL's NMT–3 was the goal of this research and development activities. In particular, originally the following goals were assigned to the author by the NMT–3 technical staff leaders (Greg Bird, Jim McNeese, Joel Williams) :

1– Design and fabricate an automation set up.

2— Step–wise automation is preferred

3— Step 1 involves automatic metering and mixing of powders

4— Step 2— automatic transport of powder to furnace location

The initial task assigned in May 91 was to get the appropriate design developed and order equipment and parts to automatically weight powders. In fact the work statement read "Create an experimental automation set up in the ME Department at UNM to automatically weigh powders using an electronic balance. Further, design the set up such that the electronic balance is reprogrammable for specific weight set points. Thus, when a set point in weight is reached by means of a vibratory feeder feeding a container on the balance, the electronic balance will send an electronic signal out to switch off the vibratory feeder".

**Deliverables were set to be :**

1— A report on the details of the automation set up as well as some experimental results and data points.

2— The hardware and the software used in the automation set up, to be delivered to NMT–3, LANL at the completion of the project.

Originally, the idea of automating various section of MCDOR centered around using a robotic arm inside the glove box (see Figures 1 and 2). After a thorough search of the pertinent literature (see Armantrout, Pedrotti, Halter, and Crossefield [1], Crowder [2], and Shahinpoor [3], [4]) it was concluded that there would be many critical problems with using robot manipulators inside the box. These problems may be outlined as:

1— Difficult to physically install a robotic arm inside a glove box unless the glove box is partially disassembled. Modular robots may be suitable but their top position accuracy is not within the tight space in dealing with nuclear powders.

2– For same reason stated in part one above it would be difficult to maintain a robotic arm inside the glove box.

3– Since a robotic arm is essentially a flexibly moving system, any possibility collision with any object inside the glove box and the walls parts of the glove box itself is highly undesirable.

4– The size and other per specifications on various powder weight, the sizes of the equipment used and other operational parameters are so strict in MCDOR that only hard (dedicated) automation appears to be the correct automation strategy.

Thus, with further guidance (see appendix A) received from the NMT–3, MCDOR automation team, the principal investigator set out to design, develop and fabricate a dedicated system to automatically weight $PuO_2$ and Ca powders, introduced by vibratory feeders into specially designed moving containers: The moving container then was to be moved to a point such that it could pour the powder into the processing furnace. Multiple Cycle Direct Oxide Reduction (MCDOR) is a semi–continuous method for directly converting plutonium dioxide to metal. This process was made possible by the insitu regeneration of the process solvent salt. The coupling of these two processes has resulted in an extremely efficient, stream–lined technique for the recovery of plutonium from its oxide.

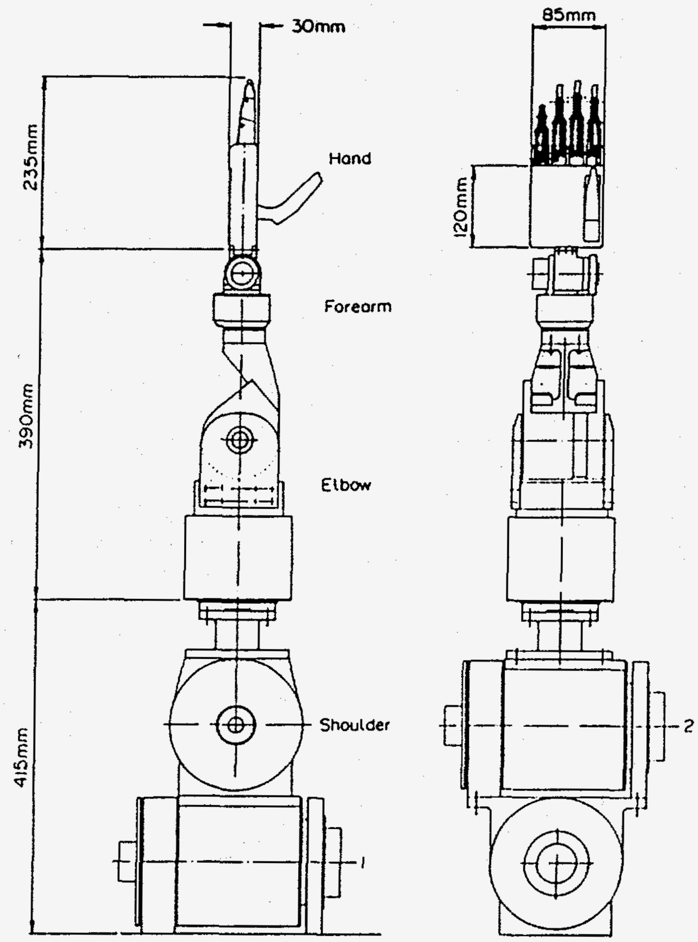



Figure 1– Design of A Glove box Manipulator According to [2]

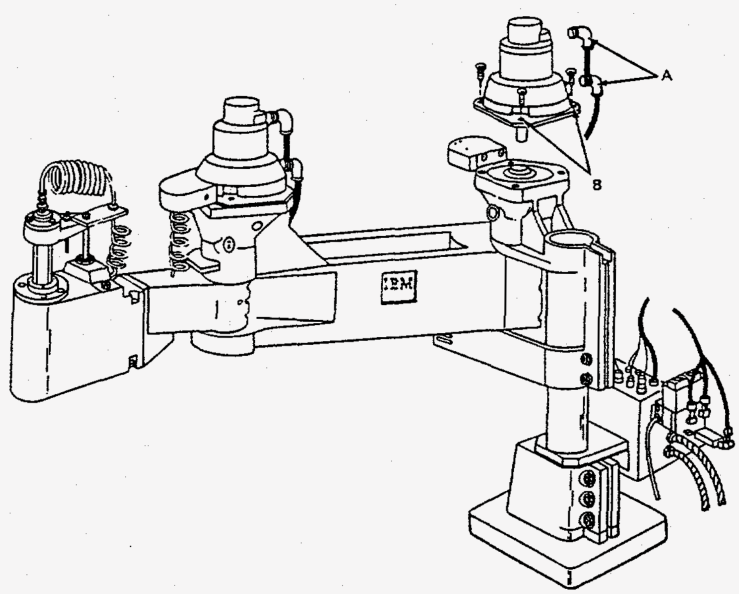



Figure 2– Design of A SCARA type robot manipulator suitable for a Glove box Environment According to [3] and [4]

The direct oxide reduction (DOR) process converts plutonium dioxide to metal using a calcium metal reductant and a calcium chloride based solvent salt at high temperature according to the following reaction:

$$PuO_2 + 2Ca \xrightarrow{800^{o}c} Pu + 2CaO \qquad (1)$$

The formation of calcium oxide (CaO) as a by–product of reaction 1 inhibits the reuse of the calcium chloride ($CaCl_2$) solvent salt because of the limited solubility of CaO in $CaCl_2$. Chlorine may be used as a chlorinating agent to convert CaO to $CaCl_2$, thus rendering the salt reusable.

$$2Cl_2 + 2CaO \xrightarrow{800^{o}c} 2CaCl_2 + O_2 \qquad (2)$$

MCDOR couples reactions 1 and 2 into repeated sequential steps during a single heating–and–cooling cycle of the reaction furnace.

See Attachment 1 for a typical MCDOR run sequence.

The MCDOR process has many demonstrated advantages over the batch processing direct oxide reduction process: (1) With the MCDOR process, significantly less salt and crucible waste is generated per kilogram of plutonium processed. Up to an 84% reduction in these solid wastes has been achieved. (2) Less plutonium is present in the discardable waste. (3) The recovery rate for plutonium in terms of kilograms plutonium per man–hour has been doubled and (4) it is believed that the operating personnel's exposure to radiation has been reduced because of fewer hands on operations. A separate study is presently underway to verify and quantify the lowering of operational exposures. This study will identify which areas will benefit the most and least from process automation and assist in identifying which processing steps should be automated and their priority.

NMT–3, has committed to the following set of operational and planning guidelines for the MCDOR Process Automation Development Program:

ENHANCE SAFETY

MAXIMIZE PERSONNEL UTILIZATION

MINIMIZE WASTE GENERATION

MINIMIZE RESIDUE GENERATION

REDUCE VAULT HOLDINGS

REDUCE MATERIAL CONTROL AND ACCOUNTABILITY (MC&A) HOLDUP

MINIMIZE PERSONNEL EXPOSURE

The MCDOR Process Automation Development Program fits into these global goals for the group extremely well. By automating or semi–automating the MCDOR process, it is firmly believed that most if not all of these group goals can be achieved.

**GOAL EXPLANATION:**

Goal: Enhance Safety

Strategy: The automation of the MCDOR process must include enhance safety as a primary development objective. It must contain technician override capability and be designed in such a manner that it contains no hidden safety traps. All equipment or automation devices are subject to review and approval by Group and Facility Safety organizations.

Goal: Maximize personnel utilization

Strategy: We would like for our people to understand the concepts and applications of automation. This can best be accomplished if we do not attempt to implement a full blown totally automated system at once. We need to approach the automation of MCDOR in steps of the appropriate size to develop our people along with the process automation. The MCDOR processing team in particular, need to be intimately involved in the development and implementation of all aspects of this program. This can only happen if we all work together as a team on a well thought out and planned program.

Strategy: We also need to develop an integrated control system. This will be partly dictated by the chemistry of the process, partly by the process sequence, and partly by the actual mechanical requirements of the system. The control system needs to be developed concurrent with the automation efforts. Our people will need to understand the control scheme and how it interfaces with the hardware. They will also need to be able to troubleshoot the control system and know when they can fix a problem and when the problem needs "professional: assistance. The hardware and control system must have either commercial support or be extremely will understood by our personnel so that we don't end up with a system that cannot be maintained in a few years. This all seems to indicate a stepwise approach to the automation and control system.

Goal: Minimize waste and residue generation strategy: One of the major drivers for the MCDOR process has been to reduce waste generation. This carries over into the control and automation of the process. We want to optimize the steps from weighing to break out and have a total system that is reliable and maintainable. Waste and residues generated because of system failures or problems are just as unacceptable as waste generated via the conventional DOR process. We want to be able to fine tune each step with the ultimate aim of integrating the entire system. We want the automation and control to fit the process rather than fitting the process to the automation and control.

Goal: Minimize personnel exposure

Strategy: In order to accomplish this goal, we need to determine which steps are the most labor intensive and which have the highest exposure rates. One no doubt follows the other but this will be verified by the radiation exposure study. The most labor intensive steps have been identified. These are weighing, loading, and bread out of the post run products. The incremental automation of these steps will helps assure that we are indeed working to meet the goal of reducing exposure and not just trading hands–on process exposure for hands–on maintenance exposure.

**PROCESS AUTOMATION DEVELOPMENT PLAN:**

Rather than attempting to automate the entire process at one time, the development activities have been broken down into segments. Each segments will be independently approached from an automation development standpoint. The final objective is to have an automated or semi–automated MCDOR process. The development segments are:

1– Reagent Preparation

2– Reagent Addition

3– Integration of Segments one and two

4– Post run Activities

5– Chlorination Instrumentation

Each of these segments will be discussed in more detail later.

Each segment will undergo thorough "cold" testing prior to glove box implementation. these tests will provide the opportunity to identify design flaws with respect to glove box operability. Modification of equipment can then occur at minimal cost. They will further provide the opportunity to establish initial processing parameters, repeatability, and establish baseline values which can be used to address accountability and criticality concerns. Following the "cold" tests, each segment will be "hot" tested for an indeterminate period of time to verify glove box operability and processing parameters. The results of these "hot" tests will assist in the planning and development of subsequent segments. Some activities will no doubt be concurrent with these tests, while others will occur sequentially. It is further recognized that planning and development of each segment must be with cognizance of the succeeding segments in order to permit whole system integration. In addition, it is clear that some of the information required to assess the success or failure of each segment can only be obtained from the "hot" tests. The results obtained from these tests will have an obvious impact on the development and implementation of subsequent segments.

It should be noted, that it is the development goal to achieve as much process automation as possible while maintaining process simplicity, operability, and maintainability. It is not a goal to totally automate the MCDOR process without regard to cost or other impacts. Each activity must be evaluated on its potential benefits to the process, its impact on other processing activities, its integration into the processing scheme, and its cost to develop and implement. Some processing steps, may indeed, never be automated. The application of robotics may be one facet of the automation effort, but it is definitely not a goal in and of itself.

## DEVELOPMENT SEGMENT EXPLANATION:

1– Reagent Preparation

This segment consists of the automated metering of the $PuO_2$ and Ca into appropriate quantities for introduction into the processing furnace. The metering devices will be interfaced with a balance and "control" system to permit remote control of these steps.

Time Frame: System in place for "hot" testing by October 1991.

2– Reagent Addition

The feed cans containing pre–measured quantities of $PuO_2$ and Ca from segment one will be attached to a metering device connected to the processing furnace. The mixture of $PuO_2$ and Ca will then be added to the molten solvent salt inside the furnace. The transfer of the feed cans containing the $PuO_2$ and Ca to the furnace metering device and their attachment to it, will be manually accomplished at this time. This will be done until the performance of the furnace metering system is fully demonstrated. The feed rate shall be variable and controllable from a location external to the glove box.

Time Frame: System in place for "hot" testing by October 1992.

3– Integration of Segments 1 and 2

Upon the successful completion of the "cold and hot" testing of segments 1 and 2, a system for transferring the $PuO_2$ and Ca container from point A (reagent preparation station) to point B (furnace station) shall be evaluated for incorporation. This system shall also permit the attachment of the $PuO_2$ and Ca container to the reagent addition device.

It is recognized, that during the development of segments 1 and 2, it will be necessary to keep in mind that the integration of the two steps may ultimately be desired. The concurrent development of this systems is not warranted. There is little point in developing this capability if either segment 1 or 2 is unsuccessful or requires significant modification. It may also be unnecessary, based on the results of the on going radiation studies.

Time Frame: Determination of need by December 1991. System in place for "hot" testing by June 1992, if decision is made to proceed with this segment.

4— Post Run Activities

Following completion of the MCDOR process, break out and disposition of the process products is required. It is a goal of this program to investigate the feasibility of automating these steps and identifying possible techniques or equipment required. this segment represents a "long range" goal and is the lowest priority.

Time Frame: Complete feasibility study by October 1992.

Decision to proceed or not with the development of a system by December 1992.

5— Chlorination Instrumentation

This activity is being pursued independently of all other aspects of the Automation Development program. It consists of a photometer for the detection of $cl_2$ in the off–gas stream from the chlorination step. Ultimately this system will be used to shut off the chlorine when the chlorination of cao is complete.

Time Frame: System in place for "hot" testing by July 1991.

**ATTACHMENT 1**

TYPICAL MCDOR PROCESS RUN SEQUENCE*
Quantity of Reagents in Grams (G)

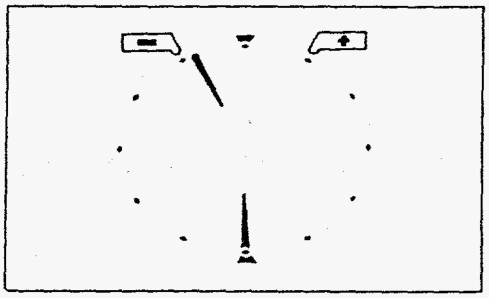
| Red. # | $PuO_2$ | Ca | $CaCl_2$ | Regn. $CaCl_2$ | Total $CaCl_2$ |
|---|---|---|---|---|---|
| 1 | 500 | 169 | 2500 | 467 | 2967 |
| 2 | 593 | 200 | 2967 | 544 | 3511 |
| 3 | 702 | 237 | 3511 | 657 | 4168 |
| 4 | 834 | 281 | 4168 | 780 | 4948 |
| 5 | 990 | 333 | 4948 | 926 | 5874 |

* The actual quantity of material added at each step may vary depending on the number of reductions desired and final quantity of metal product required.

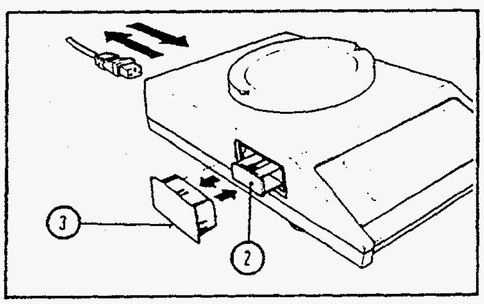
One of the fundamental components of the setup was the weighing system. Originally, this principal investigator explored the possibility of using strain gauge–equipped load cells and integrating them with a computer system. A number of these cells were purchased along with necessary electronics and a good bit of time was spent on using them to develop an automatic weighing station. The system that was developed was far from being efficient enough lacking the proper precision. It was then discovered through a thorough search of the pertinent literature that Mettler company which is a major manufacturer of electronic balances had just come up with a family of electronic balances equipped with an electronic interface called ProPac–M that could be used to automate the weighing station. It was fortunate to catch up with the frontiers of technology in automatic weighing of mass. According to company specifications [5] :

The Mettler ProPac-M has been developed especially for use in the production sector.
It consists of a terminal (entry keyboard) and a plug-in program cassette.
Connected to a Mettler PM balances, the ProPac-M provides an extremely easy way of performing the three most commonly required tasks in production.

- +/- weighing: To check that weighed materials conform to a target weight with preset tolerances. Weighing towards zero is also possible. With target weight setting, weighing-in aid (DeltaTrac) is active.
- Statistics: From a number of weighed samples the balance calculates the average weight and the standard deviation.
- Counting pieces: For counting or determining unknown quantities with the aid of freely selectable reference quantities or a fixed quantity of 10.

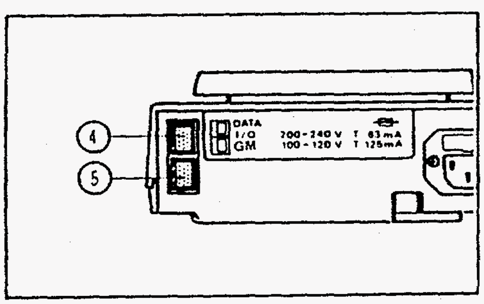


While the digital display is unbeatable for showing absolute values, the Mettler DeltaTrac is very effective for indicating relative values - e.g. a weight in comparison with reference weight, or a quantity of items. It illustrates at a glance the relationship, and also the rate of change of the relationship, and is therefore particularly suitable for weighing-in.
A real help to the user is the fact that the weighing-in aid has two accuracy ranges. The change from one range to the other is automatic. It is thus possible - with the weighing-in aid alone - to add ingredients and still achieve an accurate nominal weight.




- Unplug power cable from balance
- Detach cover (3) from left-hand side of balance (e.g. with a screwdriver). Now revealed is the standard cassette fitted in the balance before delivery. This must be replaced by the ProPac-M program cassette.
- Pull out grip of cassette (2) about 2 cm (until it stops), then use grip to withdraw cassette completely.
- Insert ProPac-M program cassette in the cassette guide, and push it right in.
- Put on cover (3) and press home (if the cover will not snap in place, the program cassette has not been pushed in fully).

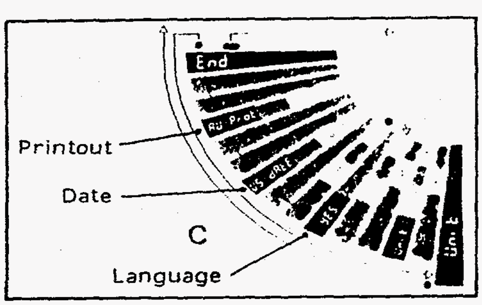
*Note: Please keep the standard cassette. It may be useful if the balance ever needs repairing.*




At the rear of the balance there are two 15-pin receptacles:

- Lower receptacle (5): is for connecting the terminal and GM units.
- Upper receptacle (4): RS232 + CL interface for connecting other equipment e.g. Mettler GA44 Printer. This is operated automatically, where appropriate, by the applications of the ProPac-M. Results can be printed out as required with the key [PRINT] on the terminal.

*Note: Coding pins on receptacles and plugs guard against wrong connections.*




You can select the language and peculiarities of different countries. This is done in sector C of the configuration file (see Operating Instructions for balance).

| | |
|---|---|
| Language: | -Yes- = English / -Oui- = French / -Ja- = German<br>-Olé- = Spanish / -Si- = Italian |
| Date: | US date = month, day, year / EU date = day, month, year |
| Printout: | SEL.Prot = printout only with [PRINT] key<br>Au-Prot = printout automatic, according to application |

Three steps are needed to enter any numbers with the decimal keyboard:

- Press required function key.

  The required function key decides what kind of numerical entry is to follow: a code number, a component weight, etc.
  Function keys are denoted F in these instructions.
  The keys [ID NR] [DATE] [TIME] [CODE] have two functions:
  When pressed once, they are function keys. Pressing the key activates the decimal keyboard, whereupon they become number (decimal) keys.
  Depending on the chosen application, other keys can also have dual functions.
  For details, see the respective applications.

- Enter number on decimal keyboard.

  Entry sequence: read number from left to right and key in.

- Press [ENTER] key.

  [ENTER] stores the entered number, allocating it to the function previously selected with the function key.

- Erase entry

  If ID NR, DATE or TIME are not to appear on the printout, these can be suppressed by keying in a line of zeros [0].

## Examples

The keys mentioned are to be pressed in the sequence given:

| | | | |
|---|---|---|---|
| To enter date (if US date configured) | e.g. 3.24.86 | [DATE] [0] [3] [2] [4] [8] [6] [ENTER] | Err 5 = Entry is incomplete, senseless or not in accordance with the configuration (EU date, US date) |
| To enter time | e.g. 9.45.38 | [TIME] [0] [9] [4] [5] [3] [8] [ENTER] | |
| To enter a target weight in grams | e.g. 83.5 g | [NOMINAL ⚖] [8] [3] [·] [5] [ENTER] | |
| To enter a reference quantity | e.g. 27 | [REF...n PCS] [2] [7] [ENTER] | |

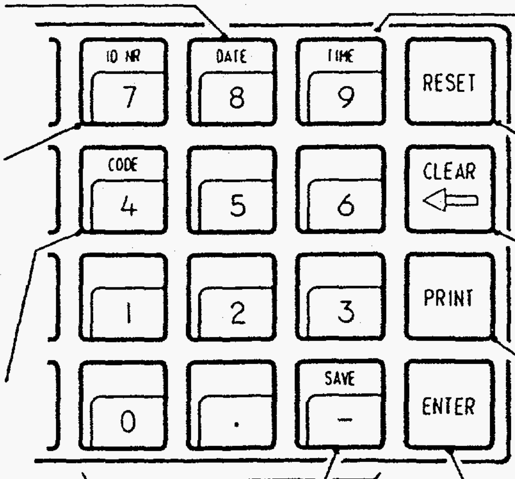
Corrections

In order to correct wrong entries already terminated with [ENTER], they must be keyed in again like new entries.

## Functions of generally used keys

(for functions of application-specific keys, see respective applications)

* Useable only with printer connected
F Function key: decimal keyboard is active for numerical entry when one of these keys has been pressed.




* F Begin data entry (6 digits, month, day, year). The date appears at the top of the printout. The calendar runs unless a power failure occurs.

* F Begin entry of identification number with max. 7 digits (e.g. operator or work position). Eraseable by pressing the key [RESET]. The ID NO appears at the top of the printout

* F Begin entry of code number with max. 7 digits and 6 decimal points, e.g. to identify each weighing task of a series. Printed at top of printout immediately after entry, and then automatically erased.

Decimal keypad: Keys 0 to 9, decimal point and hyphen. Effective after a function key has been pressed. Conclude each number entry with [ENTER] key.

Values safely stored against loss on power failure (max. 3 values). Use [SAVE] only if power failure likely. For details, see applications.

* F Begin entry for time (00 - 24 h); 6 digits, hours, minutes, seconds. Runs unless power failure. The time appears at the top of the printout.

Erases all entries except for date and time. [RESET] must always be pressed before a new weighing task.

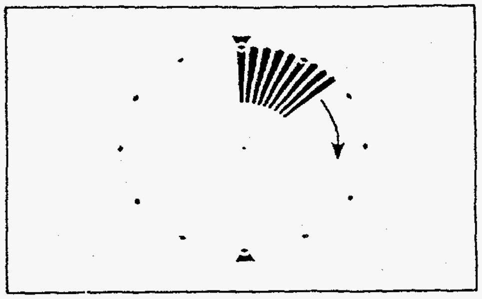
Erases the entry made with the last numerical (decimal) key pressed, then the next to last, etc., provided [ENTER] has not been pressed.

* Manual command to start printout of entries or results which are not printed out automatically (by an application).

Concludes every entry of a number on the decimal keypad.

The novel DeltaTrac® (weighing-in aid or dynamic graphic indicator) of the Mettler PM balance is controlled by the ProPac-M so that "nominal value" is indicated when the weight on the balance corresponds to the specified (key-entered) weight or quantity (according to application).
Two accuracy ranges are provided so as to give a rough picture and also fine resolution.

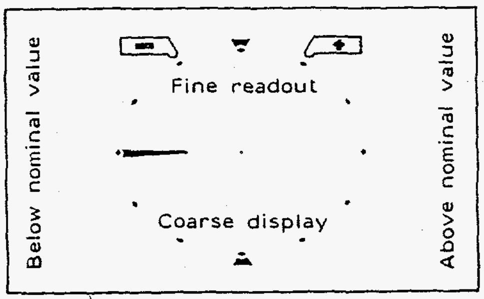
Operation of the DeltaTrac® is illustrated here with reference to a weighing-in operation on target weight (*application* +/- WEIGHING).



A container is placed on the balance and tared with the control bar.

Although the ProPac-M is connected, the display continues to function as though without ProPac-M all the time the keys on the terminal are not pressed:

The segments of the dynamic graphic display show the container weight; the digital readout stays at zero (because tared).

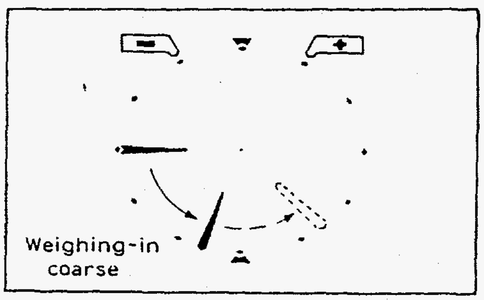



The application +/- WEIGHING is now selected and the nominal weight and also the +/- tolerances are entered.
This alters the way the dynamic graphic indicator functions:

Tolerance markers are provided to left and right of the 12 o'clock position.
These indicate the chosen +/- tolerances.
The bars indicating the container weight go out. A horizontal bar appears at the "9 o'clock" position. This is the pointer for the coarse display, and the 9 o'clock position is zero (no material has yet been weighed in).

Think of the graphic display, which is like a clock face, as divided into a lower and upper half. The lower half shows coarse readings, the upper half is the fine readout.

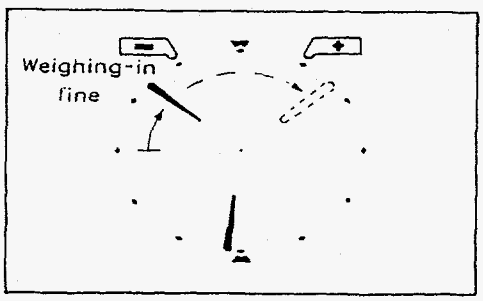
If the bars are in the left-hand half, the weight is below the nominal value. However, if the bars are in the right-hand half, the weight is above the nominal value.




**Weighing-in, coarse**

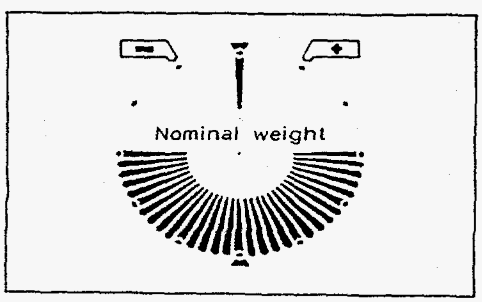
Weighed material is added briskly.

The bar previously pointing horizontally now rotates downwards.
When $^1/_3$ of the weight has been introduced, it is at 8 o'clock, with $^2/_3$ at 7 o'clock.
The nominal weight is reached when the bar points vertically downwards (6 o'clock).
(If more material (i.e. too much) is added, the bar moves on from 6 o'clock towards 3 o'clock, shown with broken lines. The 3 o'clock position denotes 100 % overfill. The bar stays here if still more is added.)




**Weighing-in, fine**

If more material is added, the fine pointer also appears (sooner or later, depending on selected minus tolerance).
It also starts at the 9 o'clock position and rotates towards 12 o'clock.
One step of the pointer corresponds to 20 % of the minus tolerance. The nominal weight is reached at the 12 o'clock position.
If still more, i.e. too much, material is added, the fine pointer moves on towards 3 o'clock, shown in broken lines. The 3 o'clock position denotes +tolerance exceeded 3-fold. The fine pointer stops here even if filling continues. At the same time, the coarse pointer can move on from 6 o'clock towards 3 o'clock.




**Nominal weight**

When the nominal weight is reached within the selected tolerances and stability is detected, all the segments in the bottom half light up, inidicating "weight O.K.".

**Typical tasks and possibilities**

- Weighing-in to a *nominal* value without using the digital readout.
- Checking for conformity to nominal weight with selectable +/- tolerances (final package check)
- Quality inspection of finished parts (e.g. injection mouldings, machined components) for defects or incompleteness

**[+/- WEIGHING]**

Activates the application +/- WEIGHING and the 3 related keys. Indicated by light-emitting diode. Tares the container weight. Erased by [RESET] or selecting another application. 12 weighing conditions can be selected. Can be protected with [SAVE].

**[NOMINAL]**

To begin entering nominal weights. This must be entered with decimal keypad. Can be protected with [SAVE]. Graphic indicator shows NOMINAL WEIGHT with coarse and fine pointer.

**[- LIMIT]**

To begin entering minus tolerance (in weight units). Can be protected with [SAVE]. This corresponds to pointer's travel from -tolerance marker to 12 o'clock. The fine pointer starts to move at -tolerance times 3. 1 step of fine pointer is equivalent to 20 % of -tolerance.

**[+ LIMIT]**

To begin entering plus tolerance (in weight units). Can be protected with [SAVE]. This corresponds to the pointer's travel from 12 o'clock to the +tolerance marker and can be entered independently of the -tolerance. The fine pointer shows up to 3 times the +tolerance, i.e. 3 o'clock. 1 step of fine pointer corresponds to 20 % of +tolerance.

<u>Weighing mode</u> can be selected provided the nominal weight has not been stored. Basic setting is [CLEAR] (CLEAR implies [3]).

- [CLEAR] Printout with stable result, without item counter
- [0] Printout when unload balance, without item counter
- [1] Printout when unload balance, with item counter
- [2] Addition mode with item counter (Display:---xy--A)
- [3] Weight O.K. with single tolerance limits
- [5] Weight O.K. with double tolerance limits
- [6] Weight O.K. with treble tolerance limits

The following 12 combinations are thuse possible:
[CLEAR] [5], [6] or [0] [3], [5], [6] or [1] [3], [5], [6] or [2] [3], [5], [6] ore base setting [CLEAR]

<u>Error messages</u>

Err 2 = Nominal weight or +tolerance entered greater than weighing range

Err 4 = Nominal weight smaller than -tolerance or -tolerance greater than nominal weight.

<u>Conditions for tolerance entries</u>

Minimum entry = Zero

Maximum entry = Nominal weight (-tolerance)
= Capacity of balance (+tolerance)

<u>Remark</u>

Protected values can be erased with [RESET] [SAVE]

Task: Fill to nominal weight 300 g, minus tolerance 1.5 g, plus tolerance 10 g, weight O.K. with double tolerance limits
(Balance type PM460 DeltaRange)

| Procedure | Press keys | Display | Printout |
|---|---|---|---|
| Select application +/-WEIGHING | [+/-WEIGHING] [5] | 0.00 g | |
| Key in nominal weight (300 g) | [NOMINAL] [3] [0] [0] [ENTER] | 0.00 g | |
| Key in minus tolerance (1.5 g) | [-LIMIT] [1] [.] [5] [ENTER] | 0.00 g | |
| Key in plus tolerance (10 g) | [+LIMIT] [1] [0] [ENTER] | 0.00 g | |
| Print out nominal weight and tolerances | [PRINT] | 0.00 g | -------------------<br>+/- WEIGHING<br>Date 01.30.86<br>Time 11.52.02<br>Nom Wgt 300.0 g<br>+ Tol 10.00 g<br>- Tol 1.50 g<br>297.2 g<br>------------------- |
| Place container on balance; tare | Control bar | 0.00 g | |
| Put in material (slightly too little shown here) | | 297.2 g | |
| Weight is O.K. (bottom half of graphic display lights up) | | 297.2 g | |

### Typical tasks and possibilities

- Counting with fixed reference number of 10. Reference optimizing possible.
- Counting with freely selectable reference number. Reference optimizing possible.
- Switching from quantity to weight unit possible at any time

### Specific key functions

**PIECE COUNTING** — Activates the application PIECE COUNTING and the 3 related keys. Indicated by light-emitting diode. Tares the container. Program erased by [RESET] or selecting another application.

**REF ∴ 10 PCS** — Sets the weight on the digital readout to 10 (switches unit to Pcs). No need to terminate with [ENTER]. Can be protected with [SAVE].

**REF ∴ n PCS** — To begin entering a reference quantity. Sets the weight on the digital readout to the reference quantity entered on the decimal keypad (switches unit to Pcs). Must be terminated with [ENTER]. Can be protected with [SAVE].

**PIECES ⬭ WEIGHT** — To switch between current quantity and weight (in the selected weight unit).

**[·]** — When in PIECE COUNTING mode, pressing the key [·] causes the current reference weight of items to appear after about 4 seconds.

### Conditions and error signals

Reference optimizing

In order to improve the counting accuracy, it can be useful to optimize the reference weight, e.g. when working with small reference numbers and large piece quantities. To do this: set up small reference number, and put a larger number of pieces on the balance. Press [ENTER] when the displayed number of pieces is stable (the reference is now optimized). Complete the counting process.

Minimum reference weight = 10 digits, otherwise "Add" lights up.

Minimum reference weight = 10 digits
Minimum item weight = ¼ digit
Err 3 = minimum item weight less than ¼ digit
Add = reference weight too small (less than 10 digits)
* flashes = reference weight between ¼ and 1 digit (appears also on the printout)

Protected values can be erased with [RESET] [SAVE]

### PIECE COUNTING (Example)

Task: Count 160 items into container with optimized reference;
reference = 5 items; reference weight of items = ? g

(Balance PM460 DeltaRange)

| Procedure | Press keys | Display |
|---|---|---|
| Select application PIECE COUNTING | [PIECE COUNTING] | 0.00 g |
| Place container on balance; tare | Control bar | 0.00 g |
| Place reference quantity of items in container (5 in this case) | | 7.56 g |
| Enter reference quantity | [REF...n PCS] [5] [ENTER] | 5 PCS |
| Increase reference number | | 28 PCS |
| Optimize reference | [ENTER] | 28 PCS |
| Call up reference weight of items | [·] | 1.500 g |
| Place items in container until quantity is reached | [PRINT] | 160 PCS |
| Switch from quantity to weight | [PIECES ↔ WEIGHT] | 240.0 g |

Printout:

```
--------------------
PIECE COUNTING
Date    01.29.86
Time    12.01.11
Ref.-W     1.514 g
out of         5 PCS
Ref.-W     1.500 g
out of        28 PCS
--------------------
Date    01.29.86
Time    12.04.14
Ref.-W     1.500 g
out of        28 PCS
Count        160 PCS
--------------------
```

**Typical tasks and possibilities**

- Determining mean value ($\bar{x}$) from a number of weighed samples
- Determining standard deviation (s) from a number of weighed samples
- Choice of number of weighed samples, also single cumulative weighing mode

| Key | Specific key functions | Conditions and error signals |
|---|---|---|
| STATS | Activates the application STATISTICS and the 3 related keys. Indicated by light-emitting diode. Erased by [RESET] or selecting another program. 2 weighing modes can be selected if sample number is zero (can be protected with [SAVE]). | [CLEAR] = single weighing (basic setting, if nothing else is selected).<br>[2] ▪ cumulative weighing (display: ---xy--A)<br>Weight difference from previous weighing must be within ± 50 %. If weight is accepted, sample number and bottom half of graphic indicator appears. |
| MAX SAMPLES n | To begin entering maximum number of samples (this entry is not obligatory). Conclude with [ENTER]. Can be protected with [SAVE]. When entered number of samples is reached, "End" lights up. | Number of samples 2 - 255<br>Err 8: entered sample number greater than 255 |
| RESULTS n,$\bar{x}$,s | To end weighing series. Successive keystrokes bring up mean value ($\bar{x}$), standard deviation (s) and number of samples (n). | |
| WEIGHT | When displaying the sample number, the zero setting can be called up with the key [WEIGHT]. If displayed value is not zero, tare. | Protected values can be erased with [RESET] [SAVE] |

## STATISTICS (Example)

Task: Weighing series with 3 samples, single weighing mode, check zero setting (Balance PM460 DeltaRange)

| Procedure | Press keys | Display |
|---|---|---|
| Select application STATISTICS | [STATS] | ----0-- |
| Key in maximum number of samples (3) | [MAX SAMPLES n] [3] [ENTER] | ----0-- |
| Place 1st sample on balance, then remove it. | | 22.56 g<br>----1-- |
| Place 2nd sample on balance, then remove it. | | 20.19 g<br>----2-- |
| Check zero.<br>Tare, if necessary | [WEIGHT]<br>Control bar | 0.03 g<br>0.00 g |
| Place 3rd sample on balance | | 23.36 g<br>----3-- |
| Remove 3. sample | | End |
| Call up results<br>- mean value<br>- standard deviation<br>- number of samples | <br>[RESULTS n, $\bar{x}$, s]<br>[RESULTS n, $\bar{x}$, s]<br>[RESULTS n, $\bar{x}$, s] | <br>= 22.037 g<br>S 1.649 g<br>---3-- |

Printout

```
--------------------
STATS
Date    01.29.86
Time    11.42.30
Max. n         3
         22.56 g
         20.19 g
         23.36 g
n              3
Mean x  22.037 g
Std. s   1.649 g
--------------------
```

Using the Pro–Pac M cartridge, an initial set up was designed by this principal investigator at UNM–ME Department during the initial 6 month of the project. The set up is schematically shown in Figure 3 below:

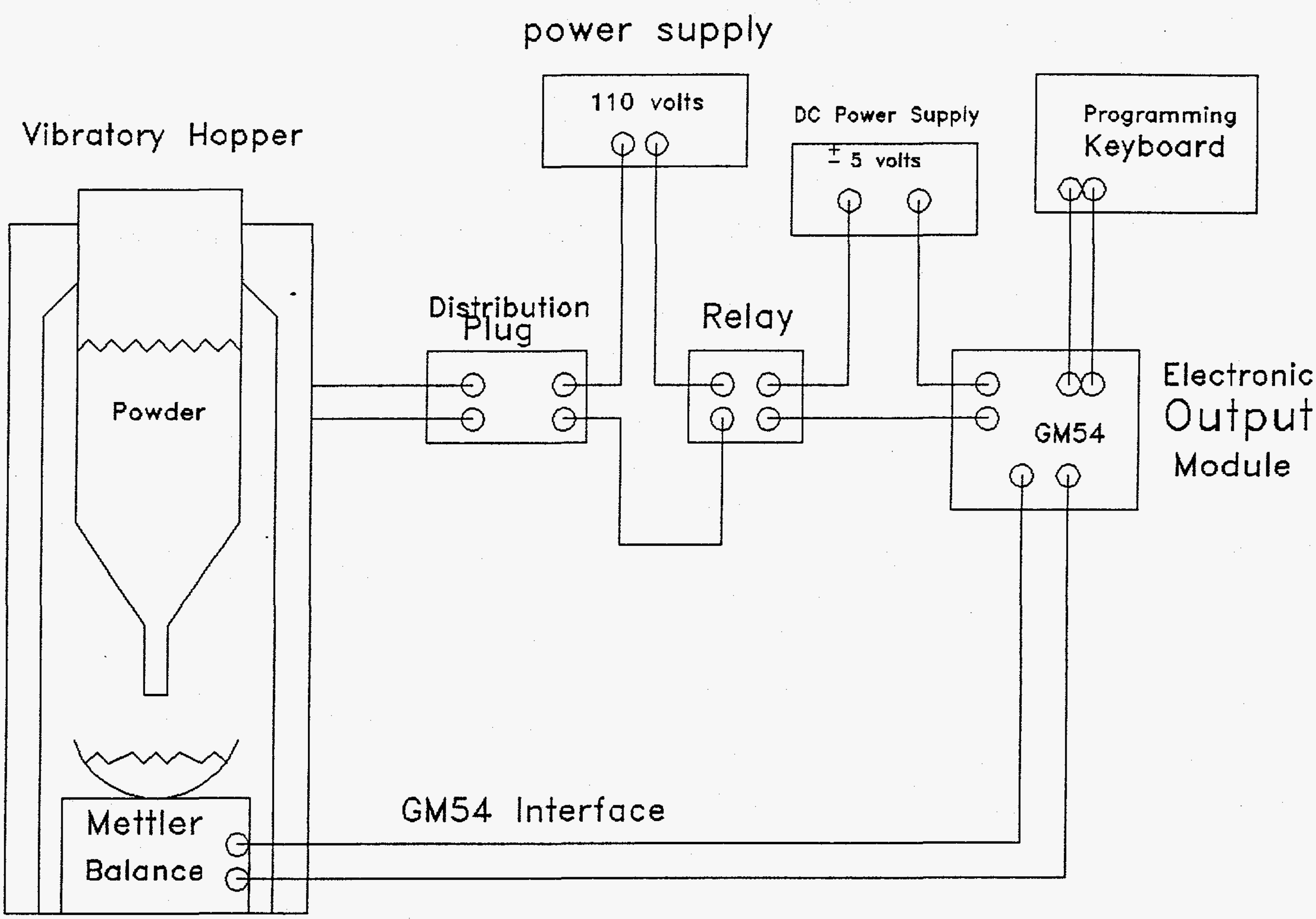



Figure 3– Initial Automation Set Up for Automatic Weighing of Powders in Conjunction With a Vibratory Feeder.

The GMS 4 automatic output module (see appendix B) enabled us to computer program, using key board, any desired weight. The basic operation of the set up was such that one could program in, using the key board, a set amount of powder, vibratory fed into a bowel, whose weight should be zeroed before the operation, with an accuracy of 1/100 th of a gram. The actual operation is listed below

1— Place container under the vibratory feeder on the PM 4000 balance.

2— Press the control bar to zero the error.

3— Connect the output number 1 t lead to the t terminal of a DC power supply set to ± 5 volts and the–lead to an input part of a 3 volt relay.

4— Place the output of the relay (generally open for part number) in the 110 volt power line for any device and, in particular, the vibratory feeder.

5— activate +/– weighting function on the key board by pressing +/– weighing key and then 5.

6— Key in target weight say 400 grams, by pressing nominal key and then 4, 0, 0 and then entering.

7— Key in minus tolerance, say 1 gram, by pressing [–tolerance] key and then 1 and enter.

8— Key in plus tolerance, say 1 gram, by pressing [+tolerance] key, 1 and then enter.

In this configuration, as soon as one pushes the enter key after step 8, the relay closes and the vibratory feeder starts to fill the bowl. Once the desired weight is reached the bottom part of the balance lights up and the relay output gets deactivated resulting in turning off of the vibratory feeder.

This automated programmable, weighing system was delivered to LANL NM–3 in the summer (July) of 1991 and was subjected to numerous tests by the staff of NMT–3 and in particular Greg Bird, Cecil Thorn and Alfonso Vargas. The results were quite satisfactory and the system meet the stringent tolerance requirement of a few grams.

It was suggested by Greg Bird [6] to apply the automated powder weighing technique, as developed in our project, to the Pinacl (pyrochemical) or the **Integrated Actinide Chloride Line Project.** The principal investigator, Mo Shahinpoor, was then instructed to start the second phase of the MCDOR automation project which was to automatically bring the container or feed cans of pre–measured quantities of $PuO_2$ and Ca powder mixtures to a location where it could be poured into the processing furnace. Since processing furnace operated at temperature above $800^0C$ the powder conveying or transport system had to be pyrolytic (fire–resistant). The system and all its components also had to be anti–corrosive in the hot chlorine environment of the furnace. Many hours of discussion between the LANL (NMT–3) technical staff and this principal investigator ensued. Clearly, it was approved that the majority of the components of the powder transport system should be placed as far away from the furnace as possible. The dimensional constraints of the intended glove box added additional complication to the intended design. The system also required a maximum 2.5 feet of height to perfectly fit the output nozzle head or the troughs of the powder mixture vibratory feeders. The vibratory feeders were fairly successfully designed and tested by Alfonso Vargas of NMT–3 who was also a member of the MCDOR automation design team. We also examined a number of commercially available vibratory feeders. However, Alfonso's design were chosen for the intended automation system because within the existing chemical, thermal and dimensional constraints, it possessed the greatest flexibility. These vibratory feeders were subsequently integrated with the designed automation setup.

After many hours of design trial, error and reviews, the following system were approved for subsequent prototyping, and was eventually built and delivered to LANL NMT–3 (See Figures 3 and 4 and Photo).

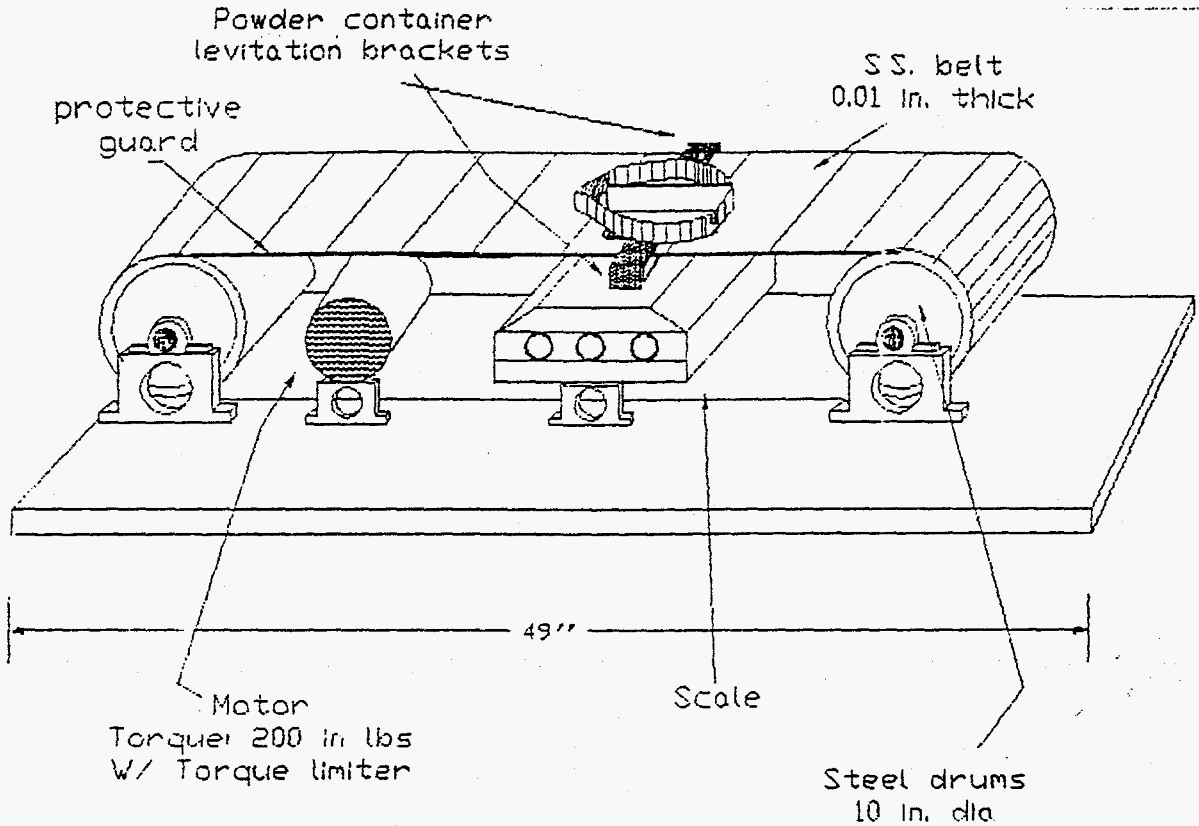



Figure 4– Schematics of the final design with all the safety features

Photo 1– The actual setup in operation at LANL NMT–3

**The Final Automation Setup**

The purpose for the Automation Setup for Powder Processing unit will be described in this work. Design requirements and fabrication procedures will be discussed. All the safety devices incorporated into the system will be described. Finally, the future design ideas and changes for the powder processing unit will be discussed.

The basic purpose for the powder processing unit is to initially begin with two separate powders and end with a mixture of these two powders without any human intervention. Two powders are automatically poured into a divided container mounted in the center of a conveyor belt. The conveyor belt is energized to rotate and as the container follows the circular path of the support drums, gravity pulls the powders from the container. At the point where the container is completely vertical, the conveyor stops which allows all the powder to fall from the container. The conveyor resumes rotation until the powder container is in the ready position to be refilled with new powders.

An important design requirement which the powder processing unit must obey is a consistent conveyor belt speed of 3 rpm. A measuring device is necessary to accurately record the mass of the powders which are initially poured into the container. Safety devices must be employed to eliminate the sharp edges of the conveyor belt and the eliminate the danger of crushing items between the conveyor belt and drums.

Initially, a few important components for the powder processing unit were provided by the customer. For example, two 10 inch steel drums and a stainless steel conveyor belt 92 inches in circumference were provided. Also, a Mettler scale was given to weigh the mass of the powders.

The powder processing unit is chain driven from a shaded pole gear motor. Specifications of the motor are 13.5 rpm, torque of approximately 200 in. lbs., and is equipped with a magnetic disc brake. In order to achieve the required 3 rpm of the conveyor belt, a 2 inch sprocket is mounted on the motor and a 4 inch sprocket is mounted on the drum. The Mettler scale rests on a support plate design with a adjustment screws to control the level of the scale. The scale is centered on the width of the belt and ball bearings were placed between the scale and the surface of the belt to eliminate any friction during belt rotation. When the powder container is located directly above the scale, the powders can be weighed (see figure 1). A total of 8 support brackets were designed and fabricated to support the drums, motor and scale. All the brackets were milled from aluminum plate 1.5 inches thick and were mounted on a large aluminum plate approximately 49 in. x 24 in. An adjustment screw mechanism was designed with drum support brackets to control the tension and alignment of the stainless steel belt.

The most important and most difficult component to fabricate for the powder processing unit was the powder container. The container needs to have two equal compartments, funnel shaped, and the inside joined area needs to have a smooth radius. The powder container was fabricated with 3 pieces of stainless steel. The pieces were molded and formed to the desired shape and joined using low temperature silver solder. A smooth radius between the sides and base of the container was achieved from milling and grinding techniques.

Several safety devices were designed for the unit. To begin with, a protective guard was designed which eliminated the sharp edge of the conveyor belt. The guard was made from 0.5 inch aluminum and follows the entire linear portion of the belt from each drum. An exposed rotating chain poses many safety risks. Therefore, a protective cover for the chain was fabricated from galvanized steel and was mounted on the drum support brackets. As a result of the large torque provided from the motor, a torque limiter was mounted on the shaft of the steel drum. Rotation of the belt can now be easily stopped in the event that an object is obstructed.

Future design ideas and changes for the powder processing unit include a completely automated system so the unit will operate in a sealed room without any human presence. Specifically, photoelectric sensors will stop and start the conveyor belt at certain stages in the path. A necessary design change is with respect to the powder container and the weighing technique. As it is designed now, the scale cannot accurately measure the mass of the powders, resulting from the large tension that exists in the belt. The future design consists of a mechanism which allows the powder container to "float" onto the scale without the tension and the weight of the belt influencing the scale. Hopefully, once the powder processing unit is complete and operational, valuable information can be obtained in the quest for new scientific technology.

**Acknowledgement**

The principal investigator is greatly indebted to the members of the technical staff of LANL NMT–3 for their support, cooperation, help and teamwork toward completion of this stage of the automation.

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# Appendix A

## MULTIPLE CYCLE DIRECT OXIDE REDUCTION PROCESS AUTOMATION DEVELOPMENT PLAN

I. Identification of processing steps to be automated.

A. Labor intensive process steps.

1. $PuO_2$/Ca weigh station.
2. $PuO_2$/Ca introduction into reaction furnace.
3. Post run break out activities.
4. Movement of SNM within glove box line.
5. Removal and disposition of SNM bearing material from glove box line.

B. High radiation dose processing steps.

1. Conduct radiation dose study to identify.

II. Prioritize processing steps to be automated.

A. High radiation dose/labor intensive process steps.

B. High radiation dose/non–labor intensive process steps.

C. Labor intensive/low radiation dose process steps.

D. Routine and/or critical equipment placement process steps.

III. Identify appropriate techniques and/or equipment to accomplish automation of processing steps.

IV. Identify procurement requirements, approximate costs, and delivery times.

V. Establish schedule for assembly of equipment, etc. and establish "cold" test procedure and success criteria.

A. Determine what tests and to what extent will be performed in Albuquerque and at what point will the equipment be transferred to Los Alamos.

VI. Establish tentative schedule for "hot" tests including procedure and success criteria.

APPENDIX B

# GM54 OUTPUT MODULE

INSTRUCTIONS FOR CONNECTION
ANSCHLUSSANLEITUNG
NOTICE DE CONNEXION
INSTRUCCIONES DE CONEXIÓN
ISTRUZIONI PER IL COLLEGAMENTO


English Page 2
Deutsch Seite 6
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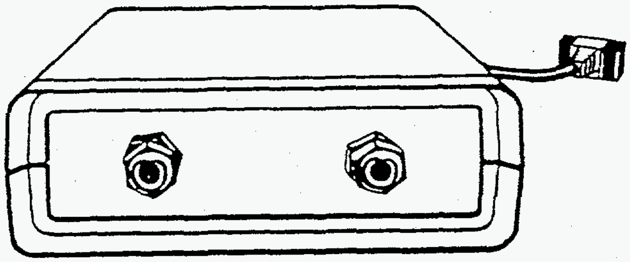
Español Página 14
Italiano Pagina 18

*Subject to technical changes and to the availability of the accessories supplied with the instruments*
Technische Änderungen und Änderungen im Lieferumfang des Zubehörs vorbehalten
Sous réserve de modifications techniques et de disponibilité des accessoires
Reservadas las modificaciones técnicas *y la disponibilidad de los accesorios*

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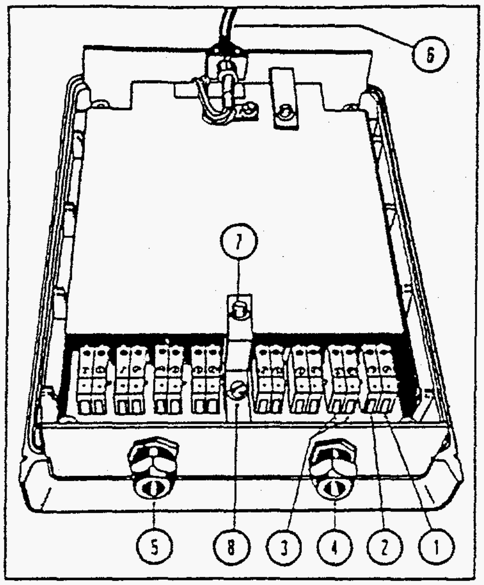
TABLE OF CONTENTS

1. Review
2. Connecting the cables
3. Technical specifications

## 1. REVIEW

The METTLER GM54 Output Module can be connected to all Mettler balances in the PM line and is used to handle contro
arising in connection with the bidirectional data interface of the PM balances or DataPac-M.
This instrument makes available 8 independent, passive digital outputs which can be addressed by a computer via the data
face. The outputs are electronically protected against overcurrents and galvanically separated from each other, as well as
the remaining control electronic, by means of optocouplers. By using an external direct current source, it is possible to
such loads as relays, valves, small DC motors and signal lamps.
These instructions for connection will tell you how to connect the instrument to the weighing system and inform you abo
technical specifications of the GM54.
To learn how the outputs are addressed by means of the software, please consult the Operating Instructions "Bidirectiona
interface of PM balances or DataPac-M".

## 2. CONNECTING THE CABLES




First open the housing before wiring the instrument:

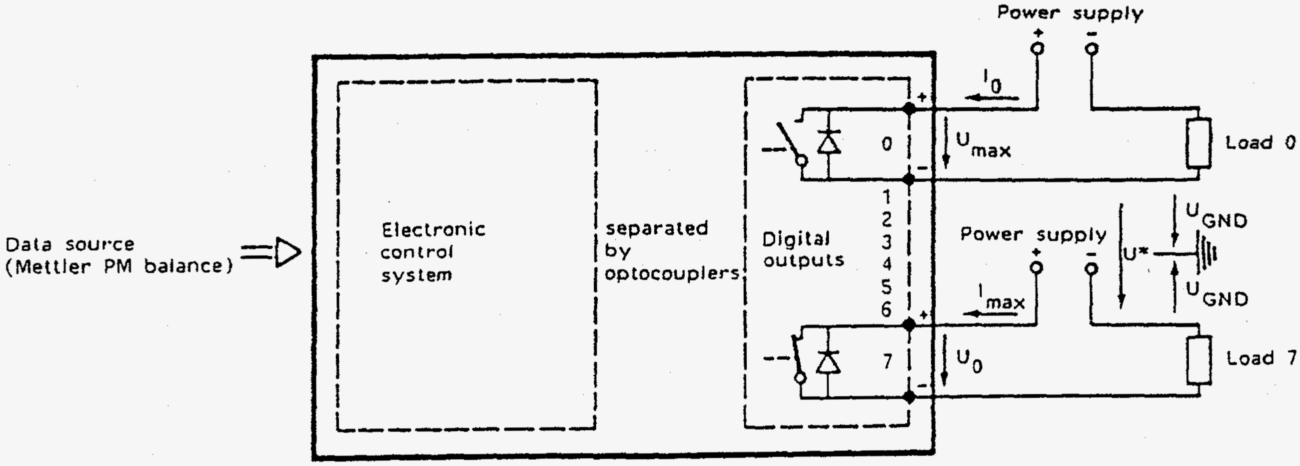
- Turn instrument upside down
- Unscrew the four screws at the bottom of the housing
- Lift off lower part of housing (the electronics and the connection terminals are located inside the cover)
  - (1) Digital output Ø (+) terminal 1
  - (2) Digital output Ø (-) terminal 2
  - (3) Digital output 1 terminals 3 (+), 4 (-) etc.
  - (4) Cable duct for digital outputs Ø, 1, 2, 3
  - (5) Cable duct for digital outputs 4, 5, 6, 7
  - (6) Fixed adapter cable for connection to the Mettler PM balance

The front plate can be removed so that the connection terminals are easier to reach when the cables are installed:

- Loosen screws (7) and (8).
- Pull out front plate with the two cable ducts
- Pull cables through the cable ducts and attach them to the terminals

Please note: To operate the instrument, it is absolutely necessary to reinstall the front plate (shielding/grounding).

For the exact technical specifications and load limits of the Output Module, please consult Chapter "3. TECHNICAL SPECIFICATIONS". When all the desired connections have been made, the instrument can be screwed tight again and connected to the Mettler PM balance (socket "GM").




Temperature range of Output Module: 10 °C...40 °C

Electronic control system: Powered by the Mettler PM balance

- Power supply: Voltage 5 V; Power consumption 40 mW

Digital outputs:

- Output open: $U_{max}$ = 36 V DC + 10 % or 24 V DC (pulsating) + 15 %
  $I_0$ ≤ 1 mA
- Output closed: $U_0$ ≤ 1,8 V, $I_{max}$ = 100 mA
- Overcurrent protection: Response threshold at a minimum of 120 mA and at least at 200 mA.
- Max. potential difference: Between ground and output: $U_{GND}$ = 65 V; between output and output: $U^*$ = 130 V
- Interference protection: Max. interference voltage against ground (static discharge of a person) = 8 kV
- Connection possibilities: Terminals for 0,75 $mm^2$, maximum length of cables about 1 km (please watch for voltage drop!).
- Please note:
  - If poles have been interchanged, i.e., in case of a wrong polarity at the digital output, the current circuit is closed over a diode.
  - In case of an overcurrent, the output in question remains open. Before placing the system again in operation, please check the corresponding circuit.

Subject to technical changes and to the availability of the accessories supplied with the instruments.

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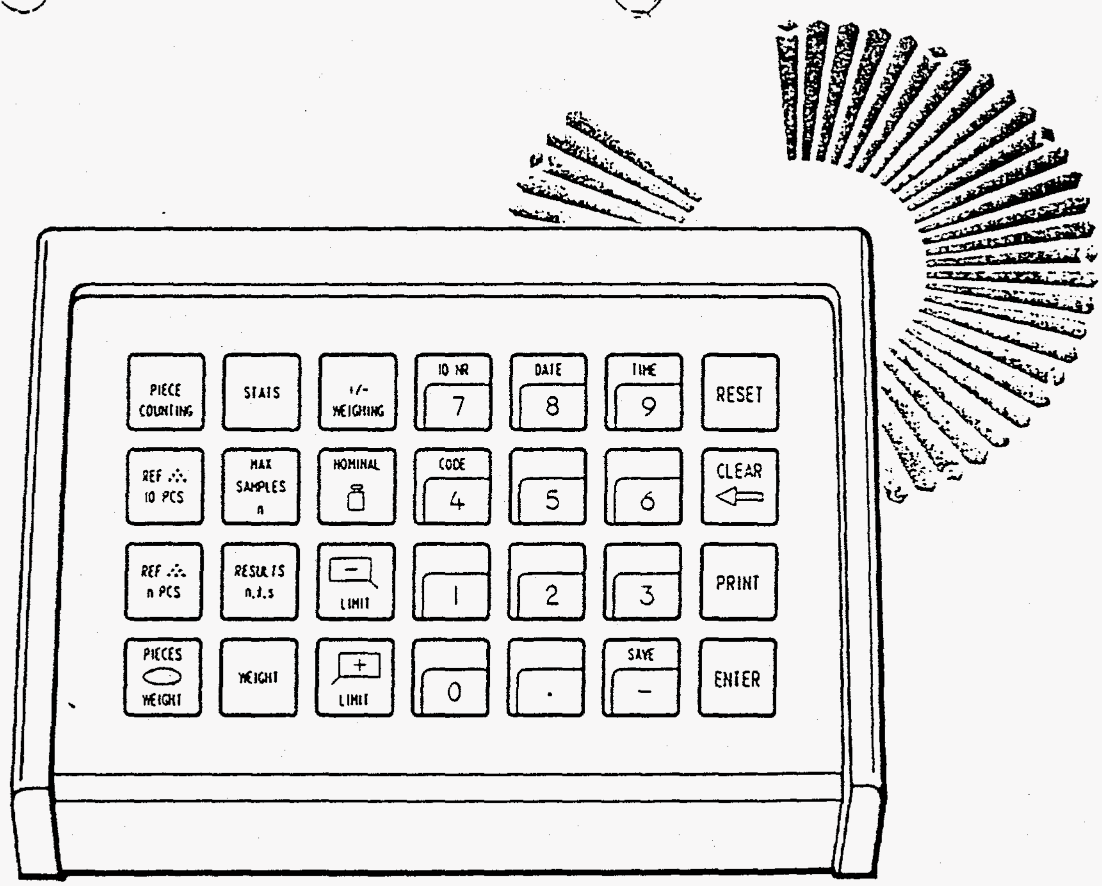
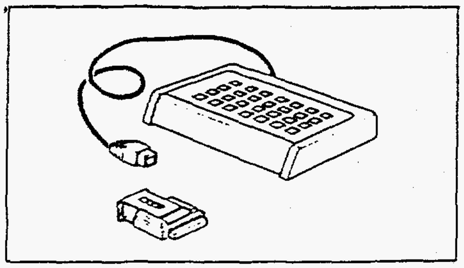
# Operating Instructions

# ProPac-M




METTLER

## The METTLER ProPac-M



The METTLER ProPac-M has been developed especially for use in the production sector. It comprises a terminal (input keypad) and a plug-in program cassette. Connected to METTLER balances employing M technology, the ProPac-M provides an extremely easy way of performing the three most commonly required tasks in production.

- +/- weighing: To check that weighed materials conform to a target weight with preset tolerances. Weighing towards zero is also possible. With target (nominal) weight setting, weighing-in aid (DeltaTrac) is activated.
- Piece counting: For counting or determining an unknown number of items with the aid of freely selectable reference piece numbers or a fixed quantity of 10.
- Statistics: For a number of weighed samples, the balance calculates the average weight and the standard deviation.

When METTLER balances of the SM series are used, there is a possibility to work with the SM terminal instead of the ProPac-M terminal. Further details are given in the Section "SM keypad" on pages 16 through 19.

## To connect the terminal and other units

Two connection sockets at the rear of the balance are provided for the following units:

Socket "DATA I/O": Units with RS232C or CL interface, e.g. GA44 Printer (for GA44 in the configuration register, section I-Face; select standard setting: S.Stb, b 2400 and interval 1 s)

Socket "GM": ProPac-M terminal and GM units with adapter plug

The coding pins in the sockets prevent improper connection.



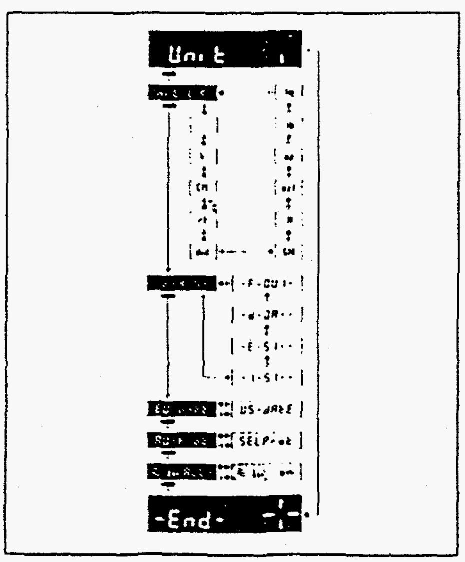


## To insert the program cassette

Insertion of the program cassette is described in the Operating Instructions of the balance used.

**Notes:**
- Before changing the program cassette, disconnect power cord of the balance (with SM balances, press key [OFF]).
- Replace standard program cassette by ProPac-M cassette.
- Please keep the standard cassette; it may be useful in subsequent use without the ProPac-M.

## Configuration register with ProPac-M




The ProPac-M can be adapted to units specific to the application. In the section -Unit- of the configuration register (see Operating Instructions of the balance, "Configuration"), the following can be selected whatever the standard software of the balance:

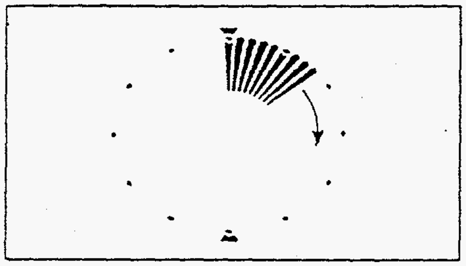
| | | | |
|---|---|---|---|
| Language: | -E -Yes- | = | English (standard setting) |
| | -F -Oui- | = | French |
| | -d -Ja- | = | German |
| | -E -Si- | = | Spanish |
| | -I -Si- | = | Italian |
| Date: | EU date | = | day, month, year (standard setting) |
| | US date | = | month, day, year |
| Printout: | Au-Prot | = | printout automatic, depending on application (standard setting) |
| | SEL.Prot | = | printout only with [PRINT] key |

**Notes:**
- If the configuration register cannot be selected, check whether the jumper of the program cassette is in position "unsecured" (cf. Operating Instructions of the balance, "Configuration")
- Reset does not reset language and date.

## The METTLER DeltaTrac

With METTLER balances employing M technology, the DeltaTrac can be used as a weighing-in aid or as a dynamic graphic display. Depending on the application, the DeltaTrac displays "target weight" when the weight on the balance corresponds to the preset (keyed in) weight value or the piece number. The display has two accuracy ranges for coarse and fine weighing.

Operation of the DeltaTrac is illustrated here with a weighing to target weight in the application +/- weighing.

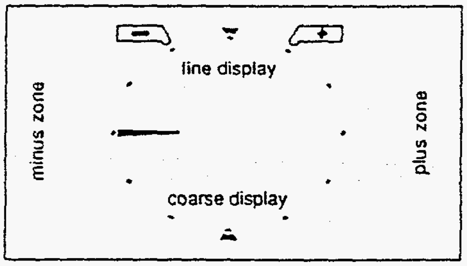


### Dynamic graphic display

A container is placed on the balance and tared with the control bar.

The display continues to function as though the ProPac-M were not connected. It does not switch over until entries are made via the keypad in an application.

The segments of the dynamic graphic display show the container weight. The digital readout remains at zero (container tared).




### Weighing-in aid

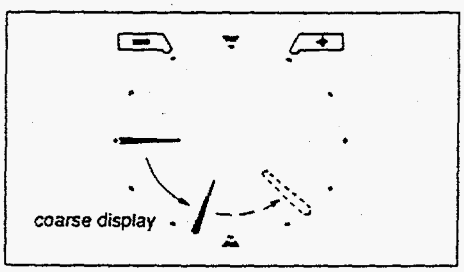
The application +/- weighing is now selected and the target weight as well as the +/- tolerances are inputted. This alters the way in which the dynamic graphic display functions:

Tolerance markers are provided to the left and right of the 12 o'clock position. These indicate the chosen +/- tolerances.
The radial bars indicating the container weight are blanked out. A horizontal bar appears at the "9 o'clock" position as the coarse display. The 9 o'clock position is the zero position (no material has been weighed yet).

Think of the graphic display, which is like a clock face, as being divided into a lower and upper half. The lower half shows the coarse reading, the upper half is the fine readout. If the bars are in the left-hand half, the weight is below the target value. However, if the bars are in the right-hand half, the weight is above the target value.



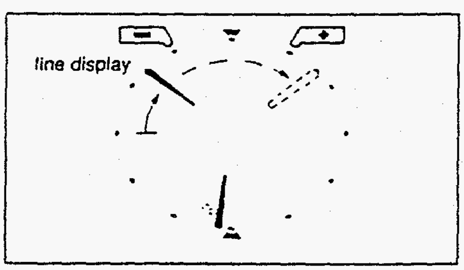





### Weighing-in, coarse (material to be weighed is added at a brisk rate)

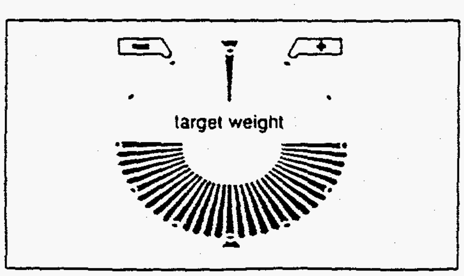
The bar previously pointing in a horizontal direction now rotates downwards. With 1/3 of the weight, it shows "8 o'clock", with 2/3 "7 o'clock". The target weight is reached when the bar points vertically downwards ("6 o'clock").

If more material is added (overfilling), the bar moves from the 6 o'clock position towards 3 o'clock (shown dashed in the illustration). The 3 o'clock position denotes 100% overfill. The bar remains in this position even if more material is added.




### Weighing-in, fine

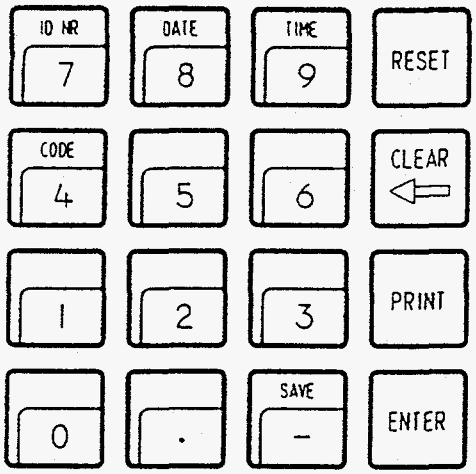
Depending on the minus tolerance inputted, the fine pointer also begins to move from the 9 o'clock position towards the 12 o'clock position when a certain fraction of the total weight is reached. One step of the pointer corresponds to 20% of the minus tolerance. In the 12 o'clock position, the target weight is reached. If still more material is added (overfilling), the fine pointer moves on towards the 3 o'clock position (shown dashed in the illustration). The 3 o'clock position signifies 3 times the plus tolerance. The fine pointer remains in this position even if filling continues. At the same time, the coarse pointer can move from 6 o'clock in the direction 3 o'clock.




### Weight OK

When the loaded weight lies within the tolerance limits and stability is achieved, all segments in the bottom half light up indicating "weight OK".

## Functions of general system keys




If a printer is connected, the date, time, identification number and code, if inputted, are printed out at the top of the printout. On power failure, the printout inscription is cleared.

| | |
|---|---|
| [ID NR] | Begin entry of identification number with max. 7 digits and 6 decimal points (e.g. user or workstation). |
| [DATE] | Begin date entry (always 6 digits). The calendar runs until a power failure occurs. Cleared by overwriting with "0". |
| [TIME] | Begin time entry (00...24 h; 6 digits, hours, minutes, seconds). The clock runs until a power failure occurs. Cleared by overwriting with "0". |
| [CODE] | Begin entry of the code number with max. 7 digits and 6 decimal points, e.g. to identify each weighing task of a series. Printed out immediately after entry and then cleared automatically. |
| [RESET] | Clears all entries except for date and time. [RESET] must always be pressed before a new weighing task. |
| [CLEAR] | Clears the entry of the last numeric key pressed (numeric keypad), then the next to last, etc. provided [ENTER] has not yet been pressed. |
| [PRINT] | Manual print command to print out entries or results which are not printed out automatically (by an application). |
| [ENTER] | Concludes the numerical input on the numeric keypad. |
| [SAVE] | Saves maximum 3 stored values to prevent loss on power failure. Use [SAVE] only if power failure likely. For details, see applications. |





## To enter values

Three steps are needed to enter values with the numeric keypad ([0] . . . [9], [.], [-]):

1. Select desired function — The selected function determines what type of value follows, e.g. a reference piece number or a target weight. The balance is now in the value entry mode. The keys [ID NR] [DATE] [TIME] and [CODE] have two functions: When pressed once, the appropriate function is selected. As pressing the keys activates the numeric keypad, the keys become numeric keys of this keypad.
2. Input the value on the numeric keypad
3. Press [ENTER] key — The value entry mode is terminated and the value assigned to the appropriate function.

**Corrections**

Wrong entries which have already been closed with [ENTER] must be corrected by reinputting them.

Entries not yet closed with [ENTER] can be cleared with [CLEAR].

**Examples**

The keys mentioned should be pressed in the specified sequence:

| | | |
|---|---|---|
| To enter date (for EU date) | e.g. 24.7.87 | [DATE] [2] [4] [0] [7] [8] [7] [ENTER] |
| To enter time | e.g. 9.45.38 | [TIME] [0] [9] [4] [5] [3] [8] [ENTER] |
| To enter a target weight in grams | e.g. 83.5 g | [+/-WEIGHING] [NOMINAL ⇩] [8] [3] [.] [5] [ENTER] |
| To enter a reference piece number | e.g. 27 | [PIECE COUNTING] [REF...n PCS] [2] [7] [ENTER] |

## +/- Weighing (information)

**Typical tasks and possibilities**

- Weighing in to a target weight (without using the digital readout)
- Checkweighing for conformity to target weight with selectable +/- tolerances (filling process control)
- Quality control of finished parts (e.g. injection moldings, machined components) for defects or incompleteness

### Specific key functions

| Key | Function |
|---|---|
| +/- WEIGHING | Activates the application +/- weighing and the three related keys (indicated by LED). Cleared by [RESET] or by selection of another application. The weighing mode can be selected (cf. page 10). |
| NOMINAL | Begin entering target weight via numeric keypad. Weighing-in aid DeltaTrac shows target weight with coarse and fine pointer. |
| − LIMIT | Begin entering minus tolerance (in weight units). It corresponds to the pointer's travel from the minus tolerance marker to 12 o'clock. The fine pointer starts to move at three times the minus tolerance.<br>1 step of the fine pointer is equivalent to 20% of the minus tolerance. |
| + LIMIT | Begin entering plus tolerance (in weight units). It corresponds to the pointer's travel from 12 o'clock to the plus tolerance marker and can be inputted independently of the minus tolerance. The fine pointer shows max. three times the plus tolerance, i.e. 3 o'clock.<br>1 step of the fine pointer corresponds to 20% of the plus tolerance. |

### Notes

- Additional conditions

  Minimum entries: 0
  Maximum entries: target weight for minus tolerance
  balance capacity for plus tolerance

- Application, target weight and tolerance can be protected against power failure with [SAVE].
- Clearing of protected values with [RESET] [SAVE].
- Animal weighing is possible with the +/- weighing. Selection of animal weighing and start of the measuring cycle are described in the Operating Instructions of the balance.

  Animal weighing with inserted ProPac-M cassette can not be triggered by the control bar (AM/ PM balances).





## +/- Weighing (example)

Task: Fill to target weight 300 g, minus tolerance 1.5 g, plus tolerance 10 g, weight OK with double tolerance limits, printout when stable, date and time set

(Balance type PM4600 DeltaRange)

| Procedure | Press keys | Display | Printout |
|---|---|---|---|
| Activate +/- weighing and select weighing mode | [+/- weighing] [5] | 0.00 g | Target weight and tolerances are printed out automatically |
| Key in target weight (300 g) | [NOMINAL [1] [3] [0] [0] [ENTER] | 0.00 g | |
| Key in minus tolerance (1.5 g) | [-TOLERANCE] [1] [.] [5] [ENTER] | 0.00 g | |
| Key in plus tolerance (10 g) | [+TOLERANCE] [1] [0] [ENTER] | 0.00 g | |
| Place container on balance, tare | Control bar | 0.00 g | |
| Add material (slightly too little here) | | 297.24 g | |
| Weight corresponds to target weight, weight OK lights up (bottom half of graphic display) | | 299.92 g | |

```
---------------------
+/- WEIGHING
---------------------
12. 09. 87       09.35
*NomWgt     300.00 g
*- Tol        1.50 g
*+ Tol       10.00 g
            299.92 g
```

## Weighing mode

The weighing mode can be selected immediately after selection of the application +/- weighing, provided no target weight has been inputted. It comprises two numbers. The possible values of these numbers, their significance and the acknowledgement in the balance display are shown in the following table.

Twelve weighing modes are available. The weighing mode can be protected against power failure with [SAVE].

Example: When the balance is unloaded, all weights should be transferred within the double tolerance limit.

Entry: [+/- weighing] [0] [5]

Display: P-O L-5

▼ await weight display

| | first number/ entry \ second number | | Weight is accepted, provided it lies within the following limits: single tolerance limits [3] | double tolerance limits [5] | triple tolerance limits [6] |
|---|---|---|---|---|---|
| Automatic printout: | when stable | [clear] | weight display (default) | P-C L-5 | P-C L-6 |
| Automatic printout: | on unloading | [0] | P-O L-3 | P-O L-5 | P-0 L-6 |
| Automatic printout: | on unloading with item counter | [1] | P-1 L-3 | P-1 L-5 | P-1 L-6 |
| Automatic printout: | in addition mode with item counter | [2] | A-2 L-3 | A-2 L-5 | A-2 L-6 |

☐ Balance display to acknowledge your entry

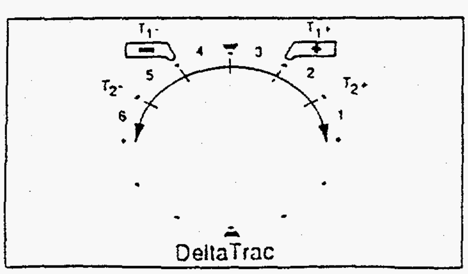




## GM54 Control

Direct attachment of the METTLER GM54 Output Module in the +/- weighing application is possible. The 8 passive digital outputs are always (independent of the selected weighing mode) controlled as follows:

| | | |
|---|---|---|
| 0 | SRE | Value is transferred |
| 1 | $x > T_2+$ | Weight x greater than $T_2+$ |
| 2 | $T_1+ < x \leq T_2+$ | Weight x between $T_1+$ and $T_2+$ or equal to $T_2+$ |
| 3 | target value $\leq x \leq T_1+$ | Weight x between target value and $T_1+$ or equal to target value or $T_1+$ |
| 4 | $T_1- \leq x <$ target value | Weight x between $T_1-$ and target value or equal to $T_1-$ |
| 5 | $T_2- \leq x < T_1-$ | Weight x between $T_2-$ and $T_1-$ or equal to $T_2-$ |
| 6 | $x < T_2-$ | Weight x less than $T_2-$ |
| 7 | | Value stable |




$T_1+$: single, positive tolerance
$T_1-$: single, negative tolerance
$T_2+$: double, positive tolerance
$T_2-$: double, negative tolerance

## Piece counting (information)

**Typical tasks and possibilities**

- Piece counting with fixed reference number of 10. Reference optimization possible.
- Piece counting with freely selectable reference number. Reference optimization possible.
- Switching from quantity to weight unit possible at any time.

### Specific key functions

| Key | Function |
|---|---|
| PIECE COUNTING | Activates the application piece counting and the three related keys (indicated by LED). Cleared by [RESET] or by selection of another application. |
| REF ∴ 10 PCS | Sets the weight on the balance equal to 10 pieces and switches unit to Pcs. |
| REF ∴ n PCS | Begin entering a reference piece number. Sets the weight on the digital readout equal to the reference quantity inputted with the numeric keypad and switches unit to Pcs. |
| PIECES / WEIGHT | Switch between current piece number and weight (in the selected weight unit). |
| · | When in piece counting mode, pressing the key [·] causes the current reference piece weight to appear for about 4 seconds. |

### Notes

- Additional conditions

  Minimum reference weight = 10 digits, otherwise "Add" lights up
  Minimum piece weight = 1/4 digit

- Application and reference piece number can be protected against power failure with [SAVE].

- Clearance of protected values with [RESET] [SAVE]

- Reference optimization

  In order to improve the counting accuracy, it can be useful to optimize the reference piece weight, i.e. when working with low piece weights and a large number of pieces.

Procedure:
- Determine reference piece weight with small number of pieces.
- Place larger number of pieces on the balance; larger number is displayed.
- Press [ENTER]. This optimizes the reference piece weight
- Even greater piece numbers can now be counted.





## Piece counting (example)

Task: Count 160 items into a container with reference optimization, reference = 5 items, time and date set, reference piece weight = ? g
(balance type PM4600 DeltaRange)

| Procedure | Press keys | Display |
|---|---|---|
| Select application piece counting | [PIECE COUNTING] | 0.00 g |
| Place container on balance, tare | Control bar | 0.00 g |
| Place reference items in container (5 in this case) | | 75.92 g |
| Enter reference piece quantity | [REF n PCS] [5] [ENTER] | 5 PCS |
| Increase piece number | | 27 PCS |
| Optimize reference weight | [ENTER] | 27 PCS |
| Call up reference piece weight | [·] | 15.403 g |
| Place items in container until piece number is reached | [PRINT] | 160 PCS |
| Switch from piece number to | | |

Printout

```
--------------------
PIECE COUNTING
--------------------
12. 09. 87     10:15
Ref .Opt
*Ref .-W     15.403 g
out of         27 PCS
--------------------
12. 09. 87     10:19
*Ref -W      15.403 g
out of         27 PCS
Count         160 PCS
--------------------
```

## Statistics (information)

**Typical tasks and possibilities**

- Determining mean value (x) from a number of weighed samples
- Determining standard deviation (s) from a number of weighed samples
- Choice of number of weighed samples as well as single or cumulative weighing mode

### Specific key functions

**STATS** — Activates the application statistics and the 3 related keys (indicated by LED). Clearance by [RESET] or selection of another application. 2 weighing modes can be selected if sample number display is zero.

**MAX SAMPLES n** — Begin entering maximum number of samples (sample number entry is not obligatory). When the inputted number of samples is reached, "End" lights up.

**RESULTS n,x̄,s** — Press once to show the mean value x. Press twice to show the standard deviation s. Press three times to show the sample number n.

**WEIGHT** — When the sample number is displayed, the zero setting can be called up with the key [WEIGHT]. If the displayed value is not zero, tare.

### Notes

- Weighing modes

  [CLEAR] = single weighing (default)

  [2] = cumulative weighing (display: - - xy - - A)

- Animal weighing is possible with the statistics application. Selection of animal weighing and start of the measuring cycle are described in the Operating Instructions of the balance. (Difference: The animal weighing cannot be triggered via the control bar of the AM/ PM balances when the ProPac-M cassette is inserted.)
- The weight difference from previous mean value must be within ±50%. If the weight is accepted, the sample number and weight OK display appear.
- Sample number 2...255
- Application and maximum sample number can be protected against power failure with [SAVE].
- Clearance of protected values with [RESET] [SAVE].





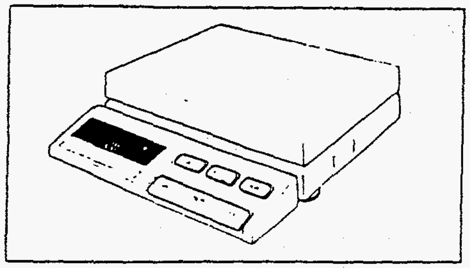
## Statistics (example)

Task: Weighing series with 3 samples, single weighing mode, check zero setting, time and date set.

(balance type PM4600 DeltaRange)

| Procedure | Press keys | Display | Printout |
|---|---|---|---|
| Select application statistics | [STATS] | - - - 0 - - - | |
| Key in maximum sample number (3) | [MAX SAMPLES n] [3] [ENTER] | - - - 0 - - - | |
| Load 1st sample then remove | | 24.29 g<br>- - - 1 - - - | ----------------------<br>STATS<br>----------------------<br>12. 09. 87 10.45<br>*Max n 3<br>1 24.29 g<br>2 22.15 g<br>3 23.57 g<br>*n 3<br>*Mean x 23.337 g<br>*Std. s 1.089 g<br>---------------------- |
| Load 2nd sample then remove | | 22.15 g<br>- - - 2 - - - | |
| Check zero<br>Tare if necessary | [WEIGHT]<br>Control bar | 0.03 g<br>0.00 g | |
| Load 3rd sample | | 23.57 g<br>- - - 3 - - - | |
| Remove 3rd sample | | End | |
| Call up result:<br>- mean value<br>- standard deviation<br>- sample number | <br>[RESULTS n,x,s]<br>[RESULTS n,x,s]<br>[RESULTS n,x,s] | <br>23.337 g<br>S 1.089 g<br>- - - 3 - - - | |

## Operation of METTLER SM balances with the SM terminal



In principle, the terminal of METTLER balances of the SM type allows the same commands to be executed as the ProPac-M terminal. After the values have been selected and saved, the ProPac-M terminal can thus be removed until a change in the setting is desired. The saving of entries and the alteration of the record inscription (date, time, code, identification number) can be effected only by use of the ProPac-M keypad, however.

**The following possibilities exist for work with the SM terminal:**

- Only the application is saved with the [SAVE] key. The values of the functions can be changed with the SM terminal after removal of the ProPac-M terminal.
- The application and the values of the functions are saved with the key [SAVE]. The values of the functions can be displayed but no longer changed with the SM terminal.

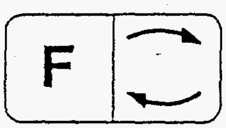
**Notes**

- Values which are not saved with [SAVE] are lost when the balance is switched off or on power failure.
- If no values are saved before switching off the balance or before a power failure, the [F] key on the SM terminal has no function.
- Clearance of saved values is performed with the keys [RESET] [SAVE] of the ProPac-M terminal.





## +/- Weighing with the SM terminal



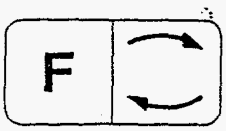

To begin an entry. The target weight appears on the digital readout, the minus or plus tolerance with the graphic display.

The target weight or the tolerance can be incremented by 1 digit (smallest display unit) by pressing the function key [F] briefly. If the function key [F] is pressed and held, the weight increases continuously.

The target weight or the tolerance can be decremented by 1 digit by pressing the switching key [⊏⊐] briefly. If the switching key [⊏⊐] is pressed and held, the weight is decreased continuously.

3 seconds after the last key operation, the displayed weight is accepted automatically. The entry can also be closed manually with the [PRINT] key.

Entry of the next function is started by pressing key [F] again.

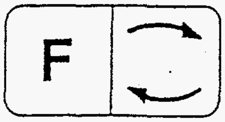



*Switching between +/- weighing and weighing mode.*
*Corresponds to the [PRINT] key (in the enter mode of the [ENTER] key) of the ProPac-M terminal.*

**Notes**

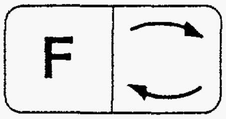
- If only the application is saved with [+/-weighing] [SAVE], target weight and tolerance can be changed as described.
- Without the ProPac-M, the weighing mode can no longer be changed.
- If the application together with target value and tolerance is saved, these can no longer be changed. The values appear on the display by pressing key [F], however.

## Piece counting with the SM terminal




Switching between current piece number and weighing mode (corresponds to key [PIECES/WEIGHT] of the ProPac-M keypad).


Corresponds to the key [PRINT] of the ProPac-M keypad.




Sets the weight on the digital display equal to the saved reference piece number or 10 items (cf. Notes). The reference piece number can not be changed with the SM terminal.

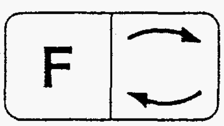
Notes

- If only the application is saved with [PIECE COUNTING] [SAVE], the reference piece number is 10.
- If the application together with the reference piece number selected by you is saved, piece counting is performed with the saved value.
- On entry of the reference piece number selected, the balance must be loaded.



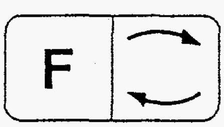


## Statistics with the SM terminal




Switching between statistics and weighing mode.


Corresponds to the [PRINT] key of the ProPac-M keypad.




Corresponds to the [RESULTS n,x,s] key of the ProPac-M keypad.

Notes

- If only the application is saved with [STATS] [SAVE], the maximum sample number is 255.
- If the application together with the sample number selected by you (Max n) is saved, the statistics are terminated when this value is reached and the results printed out.
- Without the ProPac-M, the weighing mode can no longer be changed.

## Error messages

| | | |
|---|---|---|
| Err 0 | Display/ calculation range exceeded | - Weighed number of items is larger than approx. 8'000'000<br>- Target weight or plus tolerance greater than balance capacity. |
| Err 1 | Time for input or value transfer exceeded | Entry was not ended after approx. 30 seconds or a weight value needed for calculation has not been transferred. |
| Err 2 | Input value too high | Target weight or plus tolerance greater than balance capacity. |
| Err 3 | Piece weight too small | Piece weight smaller than 1/4 digit, or reference weight smaller than 10 digits. |
| Err 4 | Tolerance too large | Minus tolerance or plus tolerance greater than target weight. |
| Err 5 | Date or time not complete or implausible | Format for both entries: XX.XX.XX (6 digit)<br>EU date: DD.MM.YY<br>US date: MM.DD.YY |
| Err 8 | Sample number too large | Sample number entry greater than 255. |

All these error messages are displayed for approx. 5 seconds. The balance then displays the weight again. The cause of the error display is ignored.

Other error messages do not originate with the ProPac-M and are explained in the Operating Instructions of the balance in question.

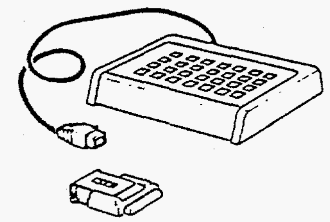




## What's wrong if ...?

| | |
|---|---|
| ... ------ is displayed? | An entry is not yet possible since the system is still occupied with a printing task or is waiting for a stable weight value. |
| ... Add is displayed? | In the determination of the reference piece weight, too few items were loaded and hence the accuracy of the counting results would be too low. |
| ... the star in the top left of the display flashes? | The reference piece weight is between 1 and 1/4 digit. |
| ... the counting system is in an indefinite condition? | Press [RESET] key, if necessary switch balance off then on. Inputs and printout parameters are cleared by this. |
| ... the display does not react to weight changes on the pan? | System is in enter mode. Close with [ENTER] is expected or clear with [CLEAR]. |
| ... the GA44 Printer prints only ****** ? | Wrong baud rate (transmission speed) setting (see Operating Instructions of the balance). |
| ... the GA44 Printer does not print every line in the record? | - The printing interval is set wrongly (correct setting is 1 second, see Operating Instructions of the balance).<br>- The printing speed is too low. The time for 20 cm paper feed should be 23...27 seconds (see GA44 Operating Instructions)<br>- Printout "Sel.Prot" in the configuration register section -Unit- is selected. Select "Au-Prot". |
| ... the printer prints continuously or after every deflection of weighing pan? | Set configuration of the interface in accordance with the balance Operating Instructions to S.Stb (send stable values). |
| ... no commands can be entered via | Entries not saved with [SAVE] are cleared on switching off the SM balance or on power |

## Overview METTLER Pacs



**CalcPac-M**
Allows further processing of weight values by calculation operations

**CountPac-M**
For demanding piece counting (with fixed and variable reference, tare preset, portion counting, totalization, etc.)

**DataPac-M**
Keypad which allows different inputs to the computer via a bidirectional data interface

**GoldPac-M**
Applications for jewelry (three units that can be called up, automatic reconciliation of weight values with inputted prices)

**LabPac-M**
Applications for the lab (differential weighing, % formula, net total)

**PharmaPac-M**
Applications for pharmaceutical products (piece counting, statistics, net total)

**ProPac-M**
Applications for production (piece counting, statistics, ±control)

**StatPac-M**
For the statistical filling process control according to different tolerance systems and pharmacopy

**XPac-M**
Allows realization of customer-specific applications