Lehr– und Didaktiksysteme
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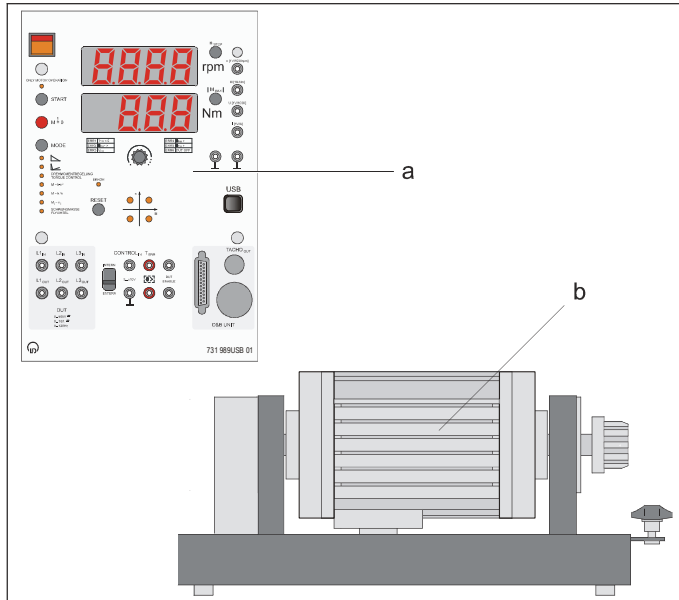
46/07-W00-Wei

Instruction Sheet   731 989USB

Machine Test System 0.3

<u>consisting of</u>
Control Unit (**a**)   731 989USB 01
Drive and Brake Unit (**b**)   731 989USB 02
[D&B Unit]

1   Area of application

The control unit -01 is used in conjunction with the D & B Unit - 02 as a testing system in the electrical machine laboratory.

The D & B Unit is a cradle-type three-phase asynchronous machine with integrated torque pick-up for connection to the control unit. This special machine is equipped with sufficient power and torque reserves to brake to standstill or drive any of the machines contained in the electrical machine system 0.3 kW. Torque pick-up is performed with strain-gauges mounted to a durable, highly elastic stainless steel bending bar and includes integrated electronics.

Overload protection is guaranteed using thermal circuit-breaker protection. Connection is carried out using a round 7-pin connector plug and a 25-pin cable contained within the scope of supply.

The control unit is a microcontroller-controlled device with integrated frequency converter for the power supply and control of the three-phase pendulum machine and display of the speed and torque measured values. Different operating modes permit manual and automatic recording of characteristics. Furthermore, the machines can approach unstable operating points, like when the squirrel-cage machines are set to lower speeds than the pull-out speeds, which are then maintained exactly by digital control loops. The recording of the characteristics, even over several quadrants, is performed point-by-point, via the XY recorder or the PC.

Technical data and additional features include:

- Power supply 230 V, 47…63 Hz, 2 kW, supplied via connection cable with earthing-pin connector

- Automatic digital speed control:

  (-5000 rpm ...0...+5000 rpm)

- Automatic digital torque control (±9.99 Nm)

- Reference variable and limiting value can be set via incremental control knob

- Automatic run-up and load characteristics

- Load simulations: Load start-up ($M \sim n^2$), Heavy load start-up ($M \sim 1/n$), arbitrary load characteristic $M_i \sim n_i$, Flywheel

- External control: -10 V...+10 V

- Switchover between two / four quadrant operation

- 26 mm seven-segment display; speed 4 digit, torque 3 digit

- Temperature monitoring: device under test (DUT[1]), D & B Unit, control unit

- Four-quadrant display for load type of DUT

- Adjustable torque limiting (overload protection) and stop speed (for automatic recording of characteristics)

- Direct measurement of DUT's voltage and current without the need of isolation amplifier

- USB interface for measured value transmission and remote control

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[1] DUT **= D**evice **u**nder **t**est – machine to be tested

- Restart inhibit can be reset after fault induced switch-off

- Analog outputs for connection of an XY recorder or display meters

- Highest safety standard: leakage current < 5 mA

Furthermore the device is equipped with a error recognition using six codes as well as protective functions. The following parameters are continuously monitored:

- Generator operation   (ERR 1)
- Temperature of the DUT   (ERR 2)
- Overvoltage in the link
  circuit of the control unit   (ERR 3)
- Temperature of the D & B Unit   (ERR 4)
- Temperature of the control unit (ERR 5)
- DUT is switched off via the
  output DUT ENABLE by removing
  the coupling guard or the
  shaft end guard   (ERR 6)

On switching on the control unit using the main switch (**a1**) and pressing the n$_{STOP}$ (**a28**) button, the Software version is shown on the displays (**a29**) and (**a30**).

2   Safety Instructions

The device is designed according to protection class 1 and corresponds to the safety stipulations laid out in VDE 0411. When the device is used according to the stipulations the safety of both the operator as well as the device is guaranteed. However, safety cannot be guaranteed if the device is used improperly or handled carelessly.

For that reason it is imperative that these instructions be read thoroughly and carefully before putting the control unit for the D & B Unit into operation and that all of the points listed below be adhered to.

This device may not be operated by persons who are unable to recognize contact hazards and incapable of meeting safety measures.

In general only work with safety connecting leads so that contact hazards with dangerous voltages can be excluded.

Modifications to the experiment set up may only be performed when the system is switched off (zero current / zero voltage). For this turn off the three-phase mains and the control unit for the D & B Unit with switch **a1**.

Before switch off operate the D & B Unit at no load by actuating pushbutton M = 0.

Always use coupling and shaftend guards to protect against contact to rotating parts.

Normally it is not necessary to open the device's housing. However, should this prove necessary, this may only be performed by a technician and only under the condition that the mains plug and all connecting leads have been disconnected.

Only apply safety extra-low voltages to the CONTROL $_{IN}$ sockets.

Never connect external voltage sources to the outputs.

Warning: This operating equipment defined class A, group 1 as set forth in the EN55011 standard and may cause radio interference in residential areas. In this case it may be required of the person operating the equipment to take necessary preventative measures and to bear the expenses. However, when the equipment is operated in the appropriate technical setting or lab of a general education or vocational institution or other training center it is assumed that no radio interference will arise in residential areas as long as a safety zone of at least 30 m exists and the operating equipment is operated only intermittently.

3   Equipment Description

3(a) Control unit
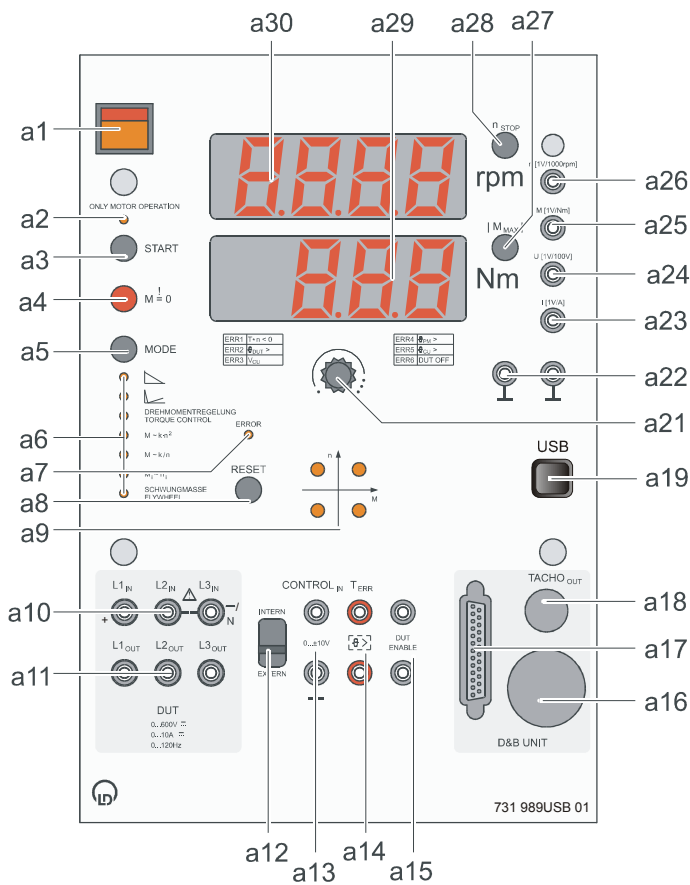
a1 Main switch

ON / OFF switch for the control electronics and supply voltages for the pendulum machine.

a2 2- or 4-quadrant operation (ONLY MOTOR OPERATION)
If this LED lights up the control unit automatically switches off when the DUT is operating in the 2nd or 4th quadrants (generator operation). This is a function used to protect power sources which are not energy recovery-proof, if the DUT is being supplied by such a source.

After the device is switched on at switch S ,the LED lights up (only 2-quadrant operation possible). If the device is switched on by pressing the START button (directly below the LED), the LED does not light up (4-quadrant operation possible).

a3 Pushbutton to start automatic recording of the characteristics.
If the operating mode load characteristic or run-up characteristic is actice, automatic recording of characteristics can be started by pressing the pushbutton. In the case of the load characteristic the speed range, starting from the momentary speed value and automatically proceeding up to the stop speed. For the run-up characteristic the machine-generator set is rapidly braked to the stop speed in order to run up again to the speed applicable for start or recording. Before starting the characteristic recording the momentary speed can be changed using the incremental control knob . At the end of the characteristic recording the

machine-generator set sheds its load and the stop speed flashes for approx. 5 seconds.

a4 The pushbutton M = 0 serves to interrupt any given operating state. At the same time the torque display shows OFF. The D & B Unit no longer develops any torque, comes to a standstill or is set to its no-load speed by the machine under test. Consequently, the activation of the pushbutton M = 0 results at all times to the load shedding of the machine-generator set. Reactivation of the pushbutton M = 0 results in the reactivation of the control unit and there with the frequency converter.

a5 Operating mode switch (MODE)
Switchover to the next operating mode occurs each time this pushbutton is pressed. The current operating mode is displayed by an LED **(a6)**.

a6 Modes of operation:

a6.1 Load characteristic
The rotation speed, specified by the incremental control knob or externally, is kept constant. The load of the DUT is the product of its speed / torque characteristic. The recording of the characteristic is started by pressing the START button.

a6.2 Run-up characteristic
The speed, which is preset using the incremental control knob or externally, is kept constant. The load of the DUT is the product of its speed / torque characteristic. The recording of the characteristic is started by pressing the START button.

a6.3 Automatic torque control (TORQUE CONTROL)
The torque, which is set by means of the incremental control knob or externally, is kept constant. The DUT operates under constant load.

a6.4 Load simulation $M \sim k\, n^2$
The D & B Unit simulates the load response of a fan ($M \sim k * n^2$ with $k = 1$).

a6.5 Load simulation $M \sim k / n$
The D & B Unit simulates the load response of a winding drive ($M \sim k / n$ with $k = 1$).

a6.6 Load simulation $M_i \sim n_i$
The D & B Unit simulates the load response with arbitrary characteristic edited by the user.

a6.7 Load simulation flywheel
The D & B Unit simulates the load response of a flywheel.

a7 Error message LED (ERROR)
A multicolored LED is situated with the following significance:

off: normal operation

green: An error has been eliminated and has to be acknowledged

red: An error appears and is displayed as ERR n
        (n stands for 1 to 6, see table below display (**a29**))

Acknowledge by pressing RESET button **(a8)**.

a8 RESET
If an error message is displayed or switch off has been carried out because the torque limit has been exceeded, the control unit can be switched on using this button. However, this is only possible if the corresponding error has been eliminated. In the case of switch-off due to overheating this entails a cooling off of the corresponding components (LED lights green).

a9 Four-quadrant display
Display of the instantaneous load type of the DUT.

Quadrant	Load type	Rotation direction
1st quadrant	*Motor operation*	*clockwise*
2nd quadrant	*Generator operation*	*couterclockwise*

3rd quadrant	*Motor operation*	*counterclockwise*
4th quadrant	*Generator operation*	*clockwise*

a10 $L1_{IN}$, $L2_{IN}$, $L3_{IN}$ resp. (-)-pole or N (Neutral)
Input sockets to the internal DUT's measurement circuits for connection of external power supply:

Input ranges for	voltages:	0…600 V AC/DC
	currents:	0…10 A AC/DC
	frequencies:	0…120 Hz

a11 $L1_{OUT}$, $L2_{OUT}$, $L3_{OUT}$
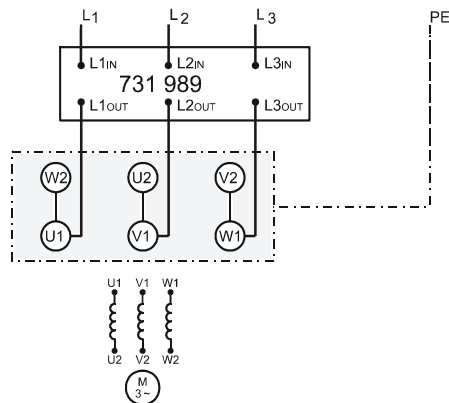Output sockets for connection of different DUT-machines (DC, AC, 3~)

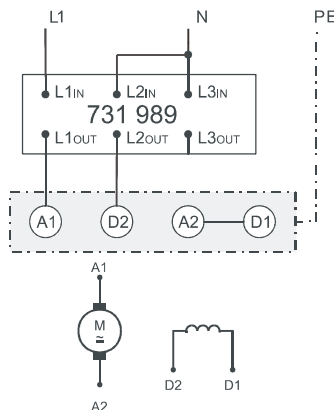Fig. 3.1   Connection of a sqirral cage motor in Δ to the sockets **a10** and **a11**

Fig. 3.2   Connection of a universal motor as an AC machine to the sockets **a10** and **a11**

a12 INTERN / EXTERN-switch
INTERN: Depending on the operating mode reference variable is set for speed, or torque via the incremental control knob.
EXTERN: Depending on the operating mode the reference variable is set for speed or torque via the external input $CONTROL_{IN}$ **(a13)**.

a13 External control input $CONTROL_{IN}$
This input is active if the INTERN / EXTERN-switch is set to EXTERN. For external operation the setpoint value for the control loop selected by the MODE button is supplied via this socket. Here the following linear relationships apply to some extent:

Automatic torque control (TORQUE CONTROL):

±10 V corresponds to ±10 N

Automatic speed control (SPEED CONTROL):

±10 V corresponds to ±5000 rpm
The setpoint value is supplied to the selected controller via a run-up generator. This means that setpoint step changes are possible and lead to a slight overshoot of the controller in question.

a14 Temperature monitoring of the DUT: T_{ERR}
This input is connected to the thermal contact of the DUT. This connection is always established as otherwise there would be no overload protection for the DUT.

a15 DUT ENABLE-sockets
Potential-free relay-driven output sockets in the operation mode as

- a switcher used with the INH input of Control Unit PWM Characterisitc Method, cat. no. 735 291,
- a cut-off used with power circuit breakers e.g. cat. no. 745 561

The operation modes *dut nc* (*n*ormally *c*losed) and *dut no* (*n*ormally *o*pen) are displayed after the lamp test as *dUE nc* or *dUE no* and can be changed by pressing the MODE key **(a5)** during the first seconds when control unit is switched on. With each pressing a delay time will be started. The setting will be saved, the default mode of DUT ENABLE is *dut no*.

a16 Connection socket to supply the D & B Unit.

a17 Control connection input
Multifunction Input for the connection of the D & B unit's build-in incremental tacho-generator, torque measurement- and protection circuits.

a18 Digital speed output ($TACHO_{OUT}$)
The signals of the tacho-generator are automatically forwarded.

a19 USB interface (USB)
This interface is electrically isolated and outputs the speed and torque of the D & B Unit. If the sockets in the DUT sockets field are connected, also the current consumption and the voltage supply of the DUT is transmitted. Control of the control unit can also be carried out using the software *CBM10*.

a21 Incremental control knob to change the reference variable and the limit
The reference variable to be changed depends on the operating mode set and thus on the control loop currently activated. The speed setpoint is varied in the operating modes load characteristic and run-up characteristic

Setting range: -5000 rpm...0 rpm...5000 rpm

In the automatic torque control mode (TORQUE CONTROL) the setpoint value for the torque control loop is varied.

Setting range: -9.99 Nm...0 Nm...+9.99 Nm

In the case of external operation the incremental control knob cannot induce a change in the setpoint.

If the stop speed or the torque limit is displayed (by pressing or, the incremental control knob can be used to vary the value currently being displayed.

Setting range stop speed: 0 rpm…+/-5000 rpm

Setting range torque limit: 0 Nm…+/-9.99 Nm

The load simulation operating modes only permit an effective setting of the torque limit, for load simulation of a winding drive (M ~ k/n) the maximum adjustable torque limit is at 5 Nm (this torque has to be overcome during start up).

a22 Auxiliary ground sockets

a23 Analog DUT's current output (I [1 V / A])
The voltage is proportional to the DUT's supply current when connected to DUT socket field (1 V corresponds to 1 A).

a24 Analog DUT's voltage output (U [1 V / 100 V])
The voltage is proportional to the DUT's supply voltage when connected to DUT socket field (1 V corresponds to 100 V).

a25 Analog torque output (M [1 V / Nm])
The voltage is proportional to the instantaneous torque of the D & B Unit (1 V corresponds to 1 Nm).

a26 Analog speed output (n [1 V / 1000 rpm])
The voltage is proportional to the momentary speed of the machine-generator set (1 V corresponds to 1000 rpm).

a27 Pushbutton to display torque limit ($|M_{MAX}|$)
When operated switchover occurs between the torque limit and the momentary torque. If the torque limit is being displayed, the display flashes. This value can now be changed using the incremental control knob.

If the display flashes, max. limit switch off (machine torque > set torque limit) is performed at the value now shown in the display. The DUT sheds its load: M = 0.

a28 Pushbutton to display speed limit n_{STOP}
When operated switchover occurs between stop speed and current speed. If the stop speed is displayed, the display flashes. This value can now be changed using the incremental control knob.

a29 3-digit 7-segment display to indicate the torque

a30 4-digit 7-segment display for the indication of the speed and error codes.
To acknowledge error see RESET **(a8)**!

3(b) Drive and brake unit
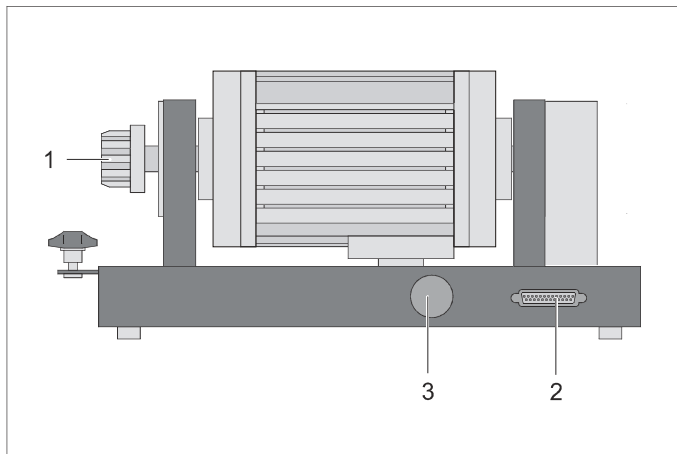
b1 Shaft with coupling
Mechanical connection between the D&B unit and the DUT using flexible rubber coupling elements.

b2 25 pole data connector
to be connected to the control unit (**a**)

b3 7 pole connector
to connect the power cord to the control unit (**a**)

4   Experiment setup

In the following the function of the Machine Test System 0.3 is described in conjunction with a squirrel-cage machine, cat. no. 732 104 as the DUT.

However any other type of machine in the 300 W machine program can be used.

Equipment list:

731 989USB	Machine Test System 0.3
735 297	Universal Converter 3 x 230 V
735 291	Control Unit PWM Characterisitc Curve Method
726 71	Single-phase Supply Unit
735 09	Load, Power Electronics
728 421	Disk CBM 10 V5
729 769	V24 Connection Cable 9-pin
731 06	Coupling
731 08	Coupling Guard
731 07	Shaft End Guard
732 104	Squirrel-cage Motor 230 / 400 V, class 0.3

5 Putting the system into operation

Here we shall describe recording of a load characteristic and the determination of rating plate data of the machine under test as a representative example.

If during the experiment procedure you deem it necessary to immediately switch off the set operating state, this is possible at any time with M = 0. The machine-generator set then comes to a standstill or continues to run at no-load.

If you switch off the device you have to activate M = 0 first to bring the motor-generator set to a standstill or no-load operation. Subsequently the mains switch of the control unit can be turned off.

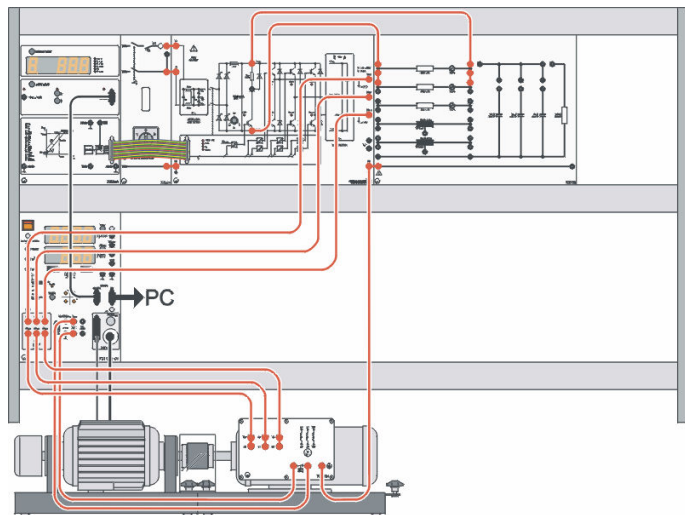Couple the DUT and the D & B Unit, see Fig. 4.1:

Fig. 4.1: Experiment setup for recording characteristics

Set the INTERN / EXTERN switch **(a12)** to INTERN.

Switch on the control unit while pressing the START button **(a3)**. All of the LEDs light up for approx. 5 seconds and *8.8.8.8.* is shown in the display. Subsequently, *dUt no* or *dUt nc* is displayed in **(a29)**.

Afterwards the displays shows 0 rpm and OFF Nm.

Now switch on the voltage supply connected to **(a10)** for the DUT. The motor-generator set rotates. The momentary speed is indicated in the display. This amounts to approx. 1480 rpm.

Now press the M = 0 pushbutton **(a4)**: the torque display shows 0 Nm.

Then select the operating mode automatic recording of the load characteristic **(a6.1)**.

Set the stop speed to –300 rpm with the aid of the pushbutton **(a28)** and the incremental control knob **(a21)**. Now set the momentary rotation speed to 1700 rpm. By pressing the START button **(a3)** the device begins with the automatic recording of the load characteristic for the three-phase asynchronous motor with squirrel-cage rotor, i. e. braking proceeds until the stop speed is reached. After completion of the characteristic recording the stop speed is flashed for approx. 5 seconds in the display. Afterwards the D & B Unit is synchronized again to the machine under test.

If the characteristic is not recorded completely this can be due to the following causes:

1. There is an ERROR message displayed (see the equipment description 2 below). After eliminating the error, e. g. the overheated components have cooled off the device is ready to resume recording of characteristics after the RESET button **(a8)** is pressed. If the DUT is overheated, this device should not be switched off but operated at no-load. The fan provides for faster cooling of the machine.

2. The torque limit has been exceeded. This is indicated by the flashing of |M$_{MAX}$|. Switch off occurs when the momentary torque value exceeds the value of the torque limit. The momentary limit value causing switch off flashes for a period of approx. 5 seconds in the display. Thereafter the momentary measurement values for torque and speed are displayed.

If the operating modes automatic recording of load characteristics **(a6.1)** or run-up characteristics **(a6.2)** are active, the speed control loop is switched on. The possibility exists to vary the setpoint value for this using the incremental control knob. This way any given speed can be set.

The recording of the load characteristic **(a6.1)** always begins at the momentary setpoint speed and ends at the stop speed. Afterwards the motor-generator set is unloaded and proceeds to run at no-load.

For the recording of the run-up characteristic **(a6.2)** the braking is always applied to motor-generator set until the stop speed is reached. Subsequently it is accelerated until the speed is reached which was in the display at the start.

As a result it is also possible to record the characteristic when the DUT is in generator operation. For this the machine under test is driven manually to the desired generator operating point and then the automatic recording of the characteristic is started.

ATTENTION: If the DUT is driven in generator operation, its power supply must be energy recovery proof. Most DC voltage sources are not energy recovery proof! If this is true for the DUT it may not be operated in the generator mode.

To protect the power source of the DUT the control unit can be switched to 2-quadrant operation **(a2)** which is the default setting after switching on the unit. An error message ERR 1 is then indicated, if the machine under test goes into generator operation.

Determining the rating plate data

The data on the rating plate of the three-phase asynchronous machine with squirrel-cage rotor are applicable for nominal motor operation. Nominal motor operation is achieved, if the machine delivers its nominal torque to the shaft, i. e. the D & B Unit has to load the motor with nominal torque:

732 104	Class 0.3	
Δ / Y	230 / 400 V	0.76 / 1.32 A
0.25 kW	S 1	cos φ 0.79
1350 rpm	50 Hz	
I.Kl. F	IP 20	

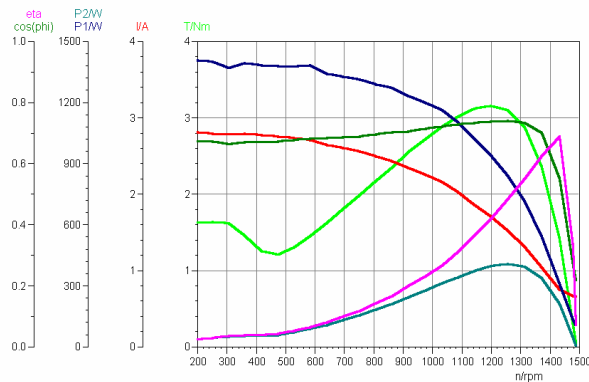Rating plate of asynchronous motor with squirrel cage rotor

Fig. 5.1: Load characteristic of a three-phase asynchronous motor with squirrel cage rotor in delta connection

The nominal torque is calculated out of the rating plate data as follows:

$M_N = P / \omega = P * 60 / (2 * \pi * n)$

$= 250\ W * 60 / (2 * \pi * 1350\ rpm) = 1.77\ Nm$

Using the MODE pushbutton **(a5)** switch on the operating mode automatic torque control TORQUE CONTROL **(a6.3)**. Now with the aid of the incremental control knob **(a21)** you can set the calculated torque below the display.

If the correct operating point has been set, the nominal current, nominal power factor and nominal speed can be determined for this machine. Since the electrical power is also measured, the efficiency of the machine can be calculated:

Measurement results:

$n = 1350\ rpm,\ I = 0.76\ A,\ \cos\varphi = 0.79,\ P_{el} = 444.2\ W$

$\eta = P_{mech} / P_{el} = 250.2\ W / 444.5\ W = 0.56 = 56\ \%$

Deviations from the values specified on the rating plate can be attributed to the machine's manufacturing tolerances, as well as the operating temperature. The permissible tolerances are listed in IEC 60034-1.

The load characteristics can be recorded point-by-point in the same manner as the rating plate data was checked. Any random torque value can be set and the corresponding operating values like speed, current, electrical power, power factor and efficiency can be determined for each setting.

On the basis of the experiments performed you should also demonstrate the operation and functionality of the control unit. Using the representative experiments carried out here similar procedures can be implemented to investigate any other DUTs from the 0.3 kW machine series. Corresponding experiment procedures can also be referred to in the experiment manuals accompanying the respective machines, see therefore in manuals EMS 10.4.x. The load simulations for fan, lifting or winding drives permit investigations of stable operating points, starting problems and the setting of frequency converter parameters.

The setting of the torque limit is carried out using the pushbutton **(a27)**. These limits are set to protect the DUT against overload in accordance with the table above. The setting should be performed before putting the DUT into operation.

6 Overview of the test machines

The following table contains the recommended values for n_{STOP} and $|M_{MAX}|$ for various DUTs:

Machine type	$|M_{MAX}|$ / Nm	n_{STOP} / rpm
731 37 Split-pole motor	9.99	-
731 86 Compound-wound mach.	3	> 50
731 91 Shunt-wound machine	3	> 50
731 92 Series-wound machine	6	> 50
732 00 Universal motor	3	> 50
732 03 Bifilar-wound motor R	9.99	-
732 04 Capacitor motor R	9.99	-
732 104 Squirrel-cage 230/400 V	9.99	-
732 11 Squirrel-cage 400/690 V	9.99	-
732 24 Squirrel-cage motor D	9.99	-
732 26 Squirrel-cage motor SW	9.99	-
732 28 Multifunction machine	9.99	-
732 37 Synchronous machine SC	9.99	-
732 45 Reluctance motor	9.99	-