

Westinghouse



Motor Load Indicators

	<u>Page</u>
General Description	
Indicating Meters.....	2, 3
Recording Meters.....	3, 17
Standard Scales.....	4
Motor Characteristics	
Ac Single Speed.....	5, 6
Ac Multi-Speed.....	6
Ac Variable Speed.....	16
Dc Single Speed.....	17
Dc Adjustable Speed Drive.....	17
Ac Adjustable Speed Drive.....	16
Current Transformers	
Fixed Ratio.....	7
Variable Ratio.....	7
Variable Ratio Tables.....	8, 9
Applications	
Ammeter Type	
Ac.....	10
Dc.....	17
Adjustable Speed.....	16
Wattmeter Type	
Polyphase Ac.....	11
Single-Phase Ac.....	12, 13
Dc.....	17
Adjustable Speed.....	16
In-Phase Current Type	
Theory.....	14
Application.....	15
Examples of Application	18
Application Table	19

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I: Function

On motor driven machinery it is often advantageous to know how much power or torque a motor is delivering. Instruments for monitoring motors are generally known as MOTOR LOAD INDICATOR OR PERCENT MOTOR LOAD INDICATORS.

Typical applications are:

(1) Grinders, saws, drills, lathes, boring or milling machines, etc., where motor load

readings can be used to optimize feed rate and depth of cut, or to monitor tool sharpness or loading.

(2) Punch presses, for indicating energy restored during the recovery portion of the cycle.

(3) Positive displacement pumps, conveyors, feeders, etc., to indicate overload, restrictions in flow or increased friction.

(4) Centrifugal pumps, blowers or fans to

indicate overloads or to assist in optimizing adjustments of vanes or dampers.

(5) Torque converters, mechanical variable speed drives, etc., to alert the operator to excessive input loads as output speeds and torques are changed.

(6) Extruders, drawbenches, wire drawing machines to indicate excessive mechanical stresses related to motor load.

(7) Other than motor loads to indicate loading on transformers, heaters, etc.

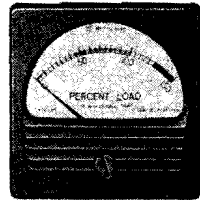
II: Available Types

Westinghouse makes motor load indicators in various electrical movements:

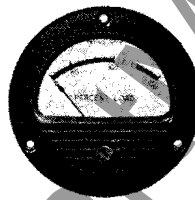
- Ac Ammeters
- Ac Wattmeters
- Ac In-Phase Ammeters
- Dc Ammeters
- Dc Wattmeters

These come in almost all commercial instrument types:

(2) Conventional Panel Instruments



R-351, N-351 - 3 1/2"



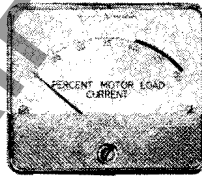
R-371, N-371 - 4 1/2"

Conventional panel instruments are conservative in style but appropriate when used on a strictly functional control panel. They have pivot-and-jewel movements so they will be subject to eventual wear-out in vibration environments or from frequent load oscillations. Sizes are 3 1/2 and 4 1/2 inches. They are quite dust-resisting normally, but can be modified for maximum dust resistance. Accuracy 2%. Price low. See DB 43-350 and PL 43-300.

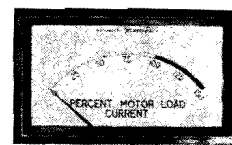
(3) Foundation Panel Instruments



Conventional Cover



Clear Plastic



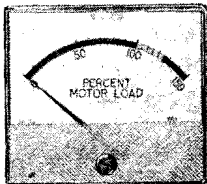
Bezel Type
Rear-of-Panel Mounting
GX-372 Only

FX-372 - 4 1/2"
GX-372 - 4 1/2"
FX-382 - 5 1/2"

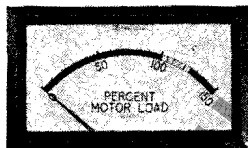
Foundation panel instruments are the deluxe models in the panel class. They have taut-band movements. The Foundation instruments are used where top quality is needed

and the price can reflect the quality. Accuracy 2%. Price is intermediate. See DB 43-370 and PL 43-300.

(1) 20/20 Panel Instruments



Clear Plastic

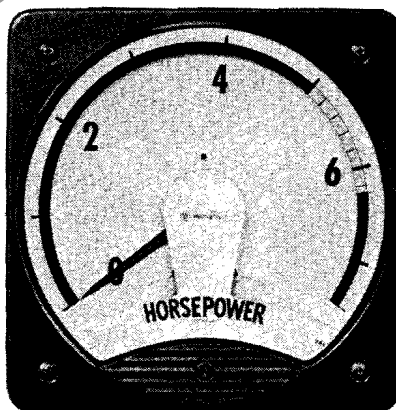


Bezel Type
Rear-of-Panel Mounting
For All Types

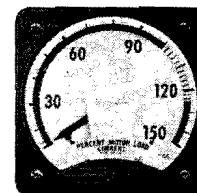
G-332 - 2 1/2", G-352 - 3 1/2"
G-372 - 4 1/2", G-382 - 5 1/2"

20/20 panel instruments are modern in styling to match the newer control accessories. They are taut-band type so will not wear out from vibrations or frequent operation. Sizes are 2 1/2, 3 1/2, 4 1/2 and 5 1/2 inches. Dust gaskets should be used in dirty environments. Accuracy class 2%. Price is low. Dull black covers are optional. See DB 43-320 and PL 43-300 for details.

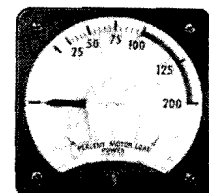
(4) Circular Scale Switchboard Instruments



K-261
250° Scale



K-241 250° Scale

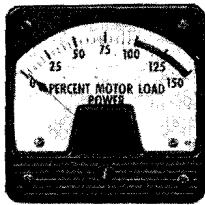


K-231 180° Scale

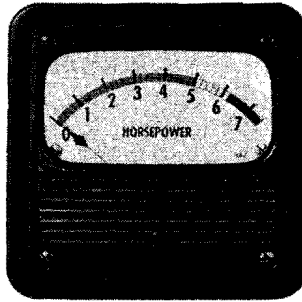
Circular scale switchboard instruments are the finest, most rugged type available. They are used on the highest quality machine tools, on top quality control panels - wherever the job demands the best. They are all taut-band, highly shock and vibration resistant and may be made highly dust and weather resistant. The accuracy class is 1%. The price is high. See DB 43-230, DB 43-240, DB 43-260 and PL 43-200.

Motor Load Indicators

(5) 100° Scale Switchboard Instruments



K-221 Flush Mounting

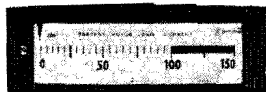


K-251 Flush Mounting

These are 100° scale switchboard instruments with the same field of application as those above. The choice of 100° scales is one of customer preference except for dc watt-

meters where only 100° is offered. All are taut-band. Accuracy 1%. Price moderate to high. See DB 43-220, DB 43-250 and PL 43-200.

(6) Edgewise Instruments

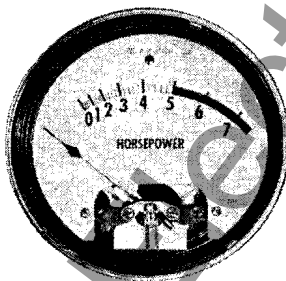


H-252

V-252

Edgewise instruments have become most popular in recent years on compact control consoles. They are all taut-band, but use in severe vibration environments should be avoided as the pointers are long and tend to vibrate more easily than on other switchboard types. Actual testing in a particular application is the preferred method for determining suitability for a specific vibration. Accuracy 1½% class. See DB 43-250 and PL 43-200.

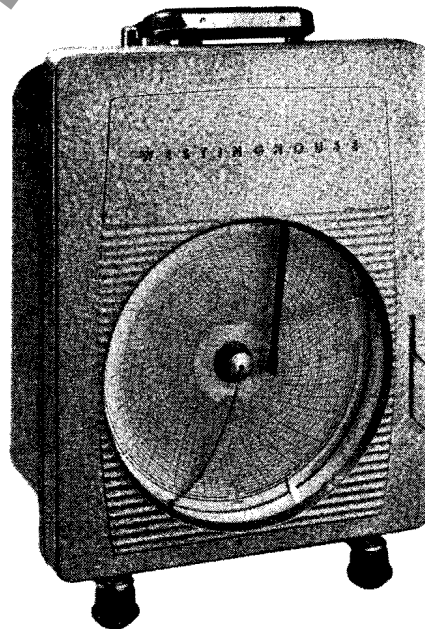
(7) Detachable Socket Meters



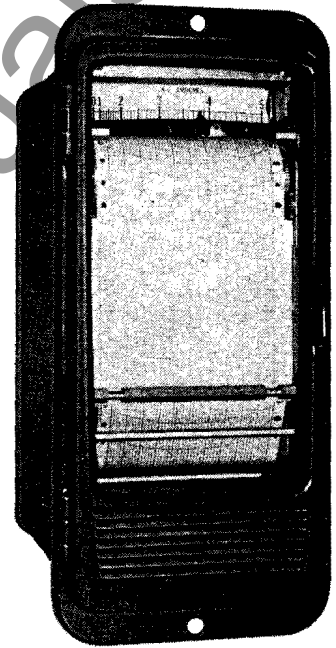
E-251

Detachable socket meters have the same movements as the 100° K-251. The enclosure is the same weatherproof socket used on watt-hour meters. This type instrument is recommended for outdoor use or around machines which are hosed down or otherwise exposed to dripping, splashing or sprayed liquids. They also serve well in dusty environments. For details see DB 43-255 and PL 43-200.

(8) Circular Chart Recording Ammeters



(9) Strip Chart Recorders



Strip chart recorders are available as ac or dc ammeters and wattmeters, either portable or switchboard mounting. See DB 43-440 and PL 43-400.

Circular chart ac ammeters are suitable for use as motor load recorders. They are built in portable and in switchboard mounting types. See DB 43-450 and PL 43-400.

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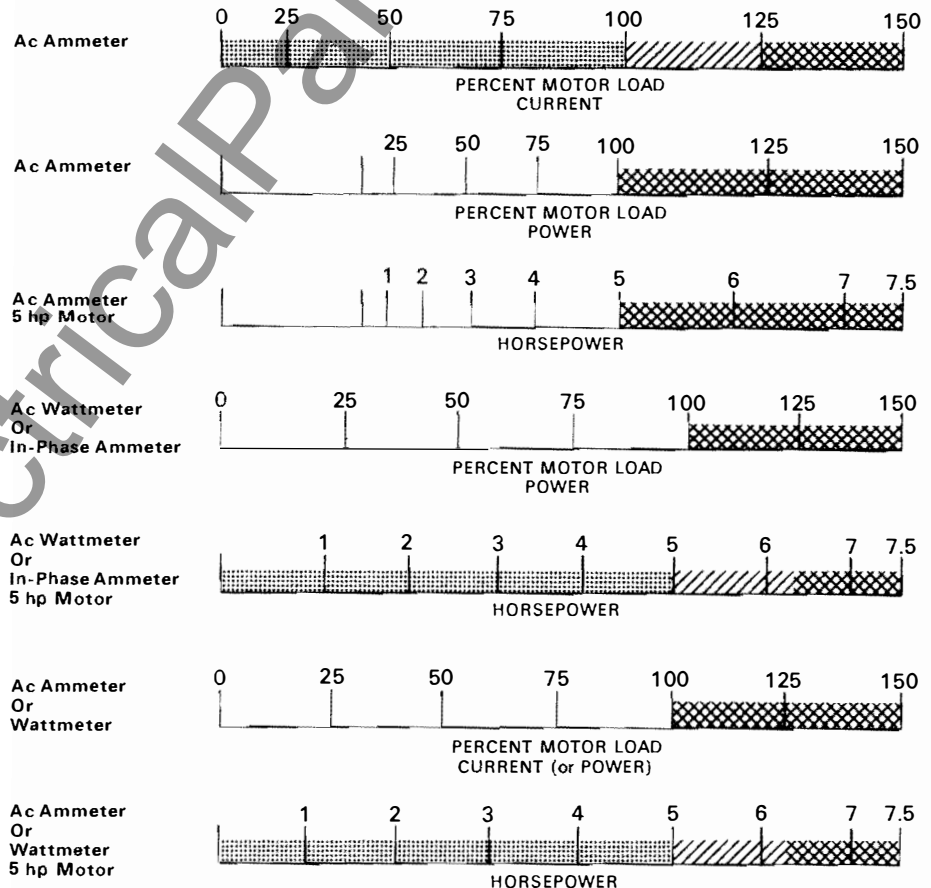
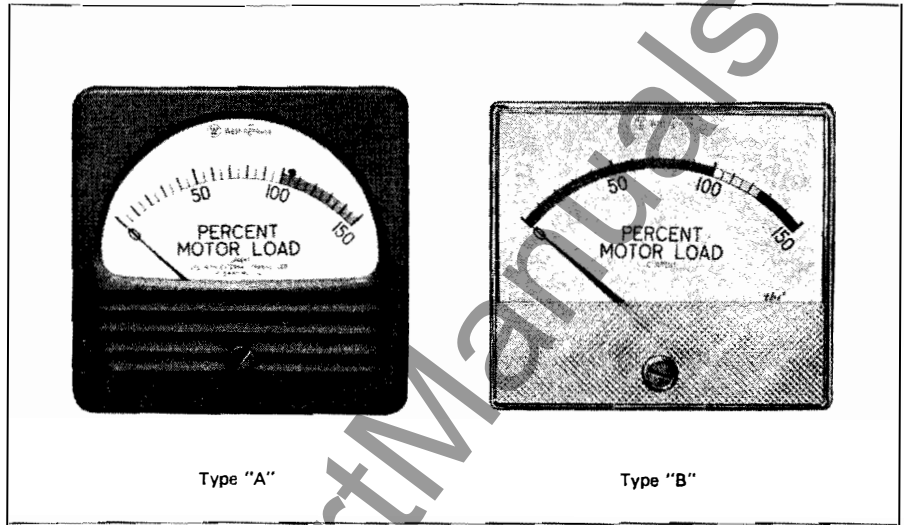
III: Standard Scales

Experience in the industry has shown that two basic scales will serve most purposes. The Type A scale has a range of 0-150 percent with a red zone from 100 to 150 percent. The Type B scale has the same range of 0-150 percent but has a green zone 0-100 percent, a yellow zone 100-125 percent and a red zone 125-150 percent. The yellow zone, indicating caution, extends to 125 percent even though most motors are incapable of continuous overload at that level. The reason for this apparent disparity is that in most applications these meters are not used to monitor continuous safe motor loading. They do, rather, most frequently indicate levels of intermittent loads which usually are carried with discretion into the 100-125 percent zone, but rarely without caution into the 125-150 percent area.

Special scale layouts can be made for specific load conditions. Legends on such instruments are generally "PERCENT MOTOR LOAD - CURRENT" "PERCENT MOTOR LOAD - POWER" or "PERCENT HORSEPOWER." The legend appropriate to specific applications will be suggested in the following text.

Typical scale distributions for each type of instrument are shown in Figure 1.

The same type indicators are used to measure other than motor loads—circuit watts, for example. In such cases the legends "PERCENT LOAD-CURRENT" or "PERCENT LOAD-POWER" are most common.



Any of these scales may have either Type A or Type B colored zones

Figure 1

Green [dotted pattern] Yellow [diagonal lines] Red [cross-hatch pattern]

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Motor Load Indicators

IV: Ac Motor Characteristics

Before going into the selection of specific load indicators it is necessary to understand how the measurable parameters (current, watts and power factor) relate to the load being measured.

(1) Figure 2 shows the typical relationship between line current or watts and the percent of rated horsepower load on a squirrel cage induction motor. These curves are averages for ratings 15 through 40 horsepower, Westinghouse Life-Line® T drip proof ac motors NEMA design B. The curves are published to illustrate a point. They will not necessarily be accurate for all ratings by all manufacturers. The actual no-load point on the current curves will vary considerably with motor rating. Figure 3 locates this point accurately for Westinghouse NEMA B motors.

(2) For actual calculations in the application of motor load indicators the motor manufacturers published information should be used. They have pretty much standardized on published test data to include:
 Full load current
 ½ load efficiency and power factor
 ¾ load efficiency and power factor
 Full load efficiency and power factor

(3) Values for power (watts) and partial load current must be calculated:

$$(a) W = \frac{hp \times 746}{eff}$$

or

$$(b) W = \sqrt{3} \times V \times A \times pf$$

and

$$(c) A = \frac{W}{\sqrt{3} \times V \times pf}$$

Published motor performance is usually based on 460 volts so formula (c) becomes —

$$(d) A = \frac{W}{pf \times 800}$$

$$(e) A \text{ (partial load)} = \frac{hp \text{ (partial load)} \times 746}{pf \text{ (partial load)} \times eff \text{ (partial load)} \times V \times \sqrt{3}}$$

A = full load current

W = full load watts input

hp = rated horsepower

eff = efficiency at full load

V = rated voltage

pf = power factor at full load

$$\sqrt{3} = 1.73$$

Indicate partial load values by using subscript W-½, pf-¾, etc.

Typical Ac Induction Motor Characteristics

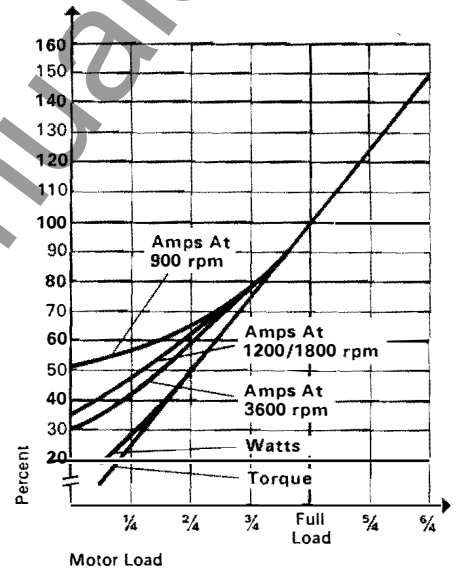


Figure 2

Ratio Of No Load Current To Full Load Current

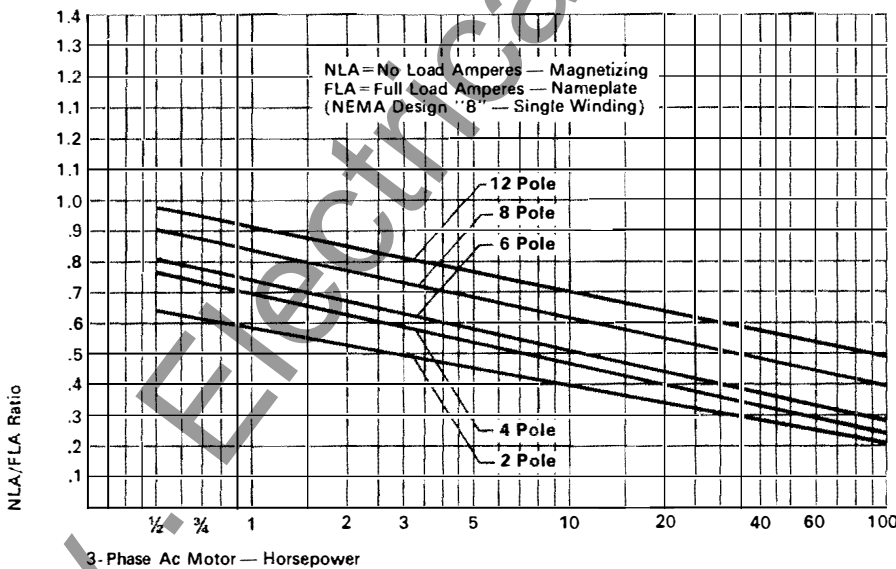


Figure 3

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IV: Ac Motor Characteristics (Continued)

(4) The proper scaling of horsepower-rated motor load indicators requires this information at 1/4, 5/4 and 6/4 load as well. If the motor manufacturer is unable to furnish full data, it will be necessary to extrapolate visually using the curves in Figures 3, 4, 5, 6 and 7 as guides to general curve trends. These curves must not be used to determine basic load data for any particular motor. Because of framesize breaks and other design variables actual test values will vary broadly.

(5) A study of Figure 2 shows how the torque and the watts follow a practically straight line throughout the load range above 1/4. Current is seen to be less direct measure of load. This is because power factor varies widely with load and with the design speed of a motor of a given horsepower. In the areas above 2/4 load the current slope does come pretty much into line with the watts. Thus, an ammeter can be used as a reliable indication of the higher motor loads only. Where this is adequate the ammeter is preferred because it is low in price. Where accurate light load indications are needed a watt-responsive indicator is necessary.

(6) Motor currents for a given load will vary with the inevitable periodic variations in line voltage. Therefore, under conditions of varying voltage an ammeter will reflect changes in current not related to motor load. There are changes in magnetizing and other reactive currents. A true wattmeter will read load accurately regardless of voltage variations.

(7) Multi-speed ac motors are built as constant horsepower, constant torque or variable torque machines. In each case, the performance curves on these motors will be radically different for each connection—usually somewhat farther apart than the curves for separate motors of the same speeds. The motor current, therefore, cannot be an indicator of load at any and all speeds. Watts, however, will be reasonably good because the efficiency curves for each speed have much the same shape. Specific applications to various ac induction motors will be covered later under the various types of motor load indicators.

(8) Variable frequency motors have a still broader spread between power factor curves for various speeds. Efficiency curves are more nearly related. Applications are quite varied. They are covered in Section IX.

How Efficiency Varies On Squirrel Cage Induction Motors With Speed:

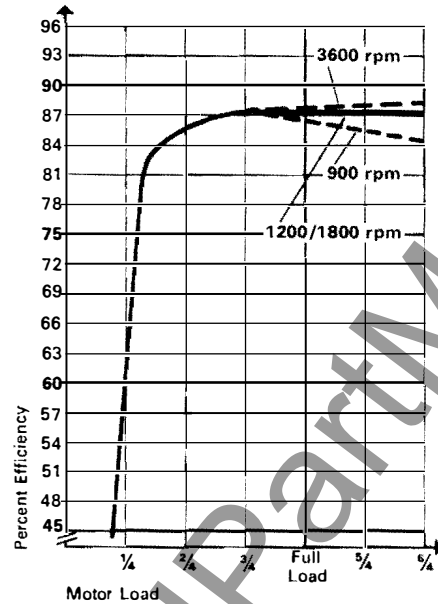


Figure 4

How Efficiency Varies On Squirrel Cage Induction Motors With Rated Horsepower:

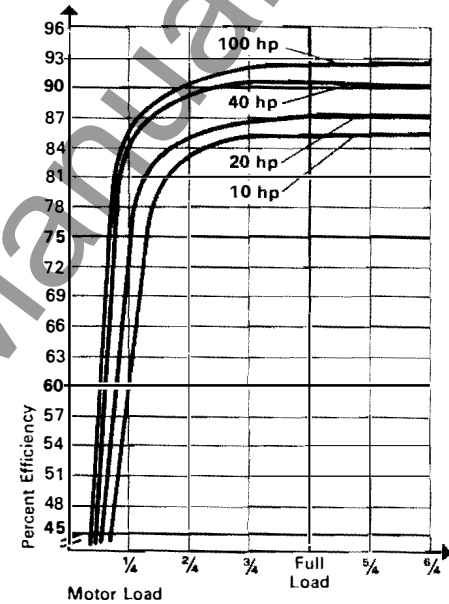


Figure 5

How Power Factor Varies On Squirrel Cage Induction Motors With Speed:

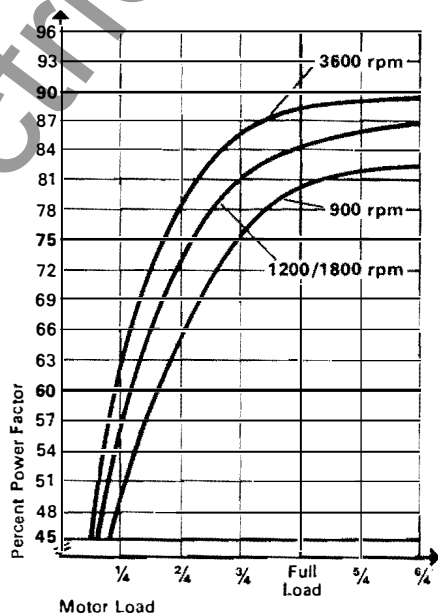


Figure 6

How Power Factor Varies On Squirrel Cage Induction Motors With Rated Horsepower:

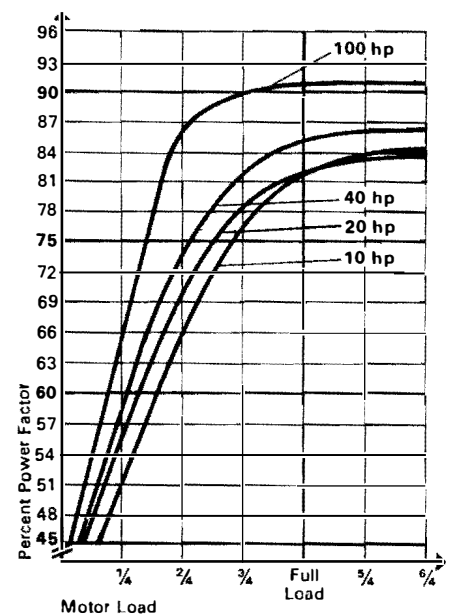


Figure 7

Motor Load Indicators

V: Current Transformers

(1) In matching a meter to a motor, one would ordinarily expect that the motor currents are fixed by design and that the meter calibration would have to be variable. This is the case on switchboard instruments where odd current ratings are normally available, but to maintain the low cost of panel instruments it is essential to standardize ratings and to introduce a variable device between the motor and the meter. Such a device is the variable ratio current transformer, Westinghouse Type ECI, (see DB 44-112 in the Instrument Transformer Section of the Westinghouse catalog).

(2) The ECI transformer is of "doughnut" construction, where the primary conductor is passed directly through the "hole". The transformer ratios are 100:5, 150:5, 200:5, 250:5, 300:5, 400:5, 500:5, 600:5 and 800:5. Each ratio can be reduced in even multiples by looping the primary conductor through the "hole" two or more times. A transformer having a ratio of 200:5 will be changed to 50:5 amperes if four loops or turns are made with the primary conductor as illustrated in Figure 8.

(3) The ratio can be further trimmed by winding turns of the secondary lead through the transformer "hole". Turns in the direction of the fixed secondary winding effectively add secondary turns and those in the opposite direction effectively subtract secondary turns. Figure 9 shows how turns may be

added to the secondary winding by connecting to the "non-polarity" (X2) terminal and winding on turns in the direction of the arrow. Figure 9 shows how these same turns will be subtracted when connected to the "polarity" (X1) terminal.

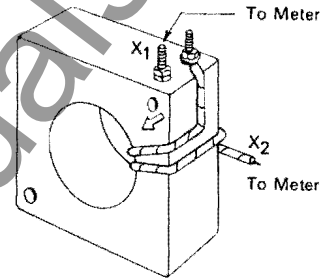
The fixed secondary windings have an increasing number of turns as the ratio increases. The 100:5 rating has a 20:1 ratio and has 20 fixed secondary turns. The addition or subtraction of each external secondary turn will adjust the effective ratio by 5 percent. The 200:5 rating has a 40:1 ratio and 40 secondary turns, so external turns will each adjust the effective ratio by 2½ percent.

For convenience, a table (Figure 10) has been worked out in terms of the primary current for a 5 ampere secondary output. Relationships noted in the previous paragraph suggest that these tables may be extrapolated on a straight line basis.

It will usually not be possible to obtain a primary current exactly equal to that calculated for an application, but there will be combinations well within the accuracy capability of the system.

(4) Type ECI transformers have a continuous current rating factor of 1.33 at 30°C ambient. In motor load applications they are usually sized 150 percent of the motor full load current. Motors have service factors of 1.15 or less, so even with the lowest power factors, the ECI transformers will have a load

Two Added Secondary Turns



Two Subtracted Secondary Turns

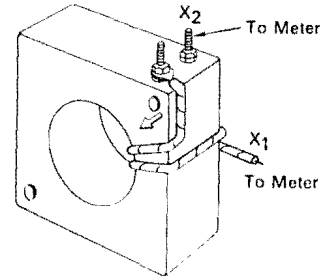


Figure 9

capability greater than the associated motor.

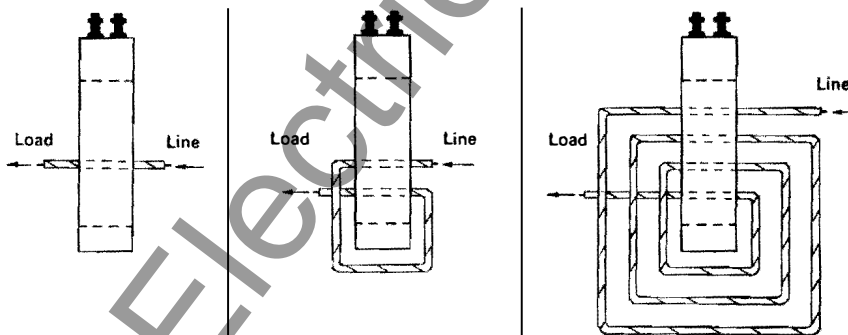
(5) Type ECI transformers saturate on open secondary without developing the extremely high voltages normally associated with open-circuited current transformer secondaries. These transformers may therefore be switched without make-before-break contacts or may be left with secondaries disconnected. Switches must be suitable for 600 volt ac service.

(6) On larger motor control equipments there will usually be single fixed-ratio transformers already in place. It is possible to use one of these with a motor load indicator having a special end scale current rating. The ammeter full scale current will be:

$$I \text{ (end scale)} = \frac{A \times 1.5}{r}$$

where A = full load current of motor
r = current transformer ratio

Special switchboard class ammeters take a moderate price adder. Special panel instruments, because of their less flexible design, may be relatively expensive unless quantities are large. A good rule of thumb suggests using separate multi-ratio transformers for the motor load indicators unless more than two identical switchboard or 10 panel types are required. Two speed motors always require separate multi-ratio transformers to avoid the complication of dual-rated instruments and switching.



1 Primary Turn		2 Primary Turns		4 Primary Turns	
Nameplate Ratio	Actual Ratio	Nameplate Ratio	Actual Ratio	Nameplate Ratio	Actual Ratio
100:5	100:5	100:5	50:5	100:5	25:5
150:5	150:5	150:5	75:5	150:5	37.5:5
200:5	200:5	200:5	100:5	200:5	50:5
250:5	250:5	250:5	125:5	250:5	62.5:5
300:5	300:5	300:5	150:5	300:5	75:5
400:5	400:5	400:5	200:5	400:5	100:5
500:5	500:5	500:5	250:5	500:5	125:5
600:5	600:5	600:5	300:5	600:5	150:5
800:5	800:5	800:5	400:5	800:5	200:5

Figure 8

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V: Current Transformers (Continued)

Table to Determine Needed Number of Primary and Secondary Turns (ECI Transformers)

Primary Current for Secondary Current of 5 Amperes									Primary Turns	Secondary Turns
100/5 Ratio	150/5 Ratio	200/5 Ratio	250/5 Ratio	300/6 Ratio	400/5 Ratio	500/5 Ratio	600/5 Ratio	800/5 Ratio		
150	200	250	300	350	450	550	650	850	1	+10
145	195	245	295	345	445	545	645	845	1	+ 9
140	190	240	290	340	440	540	640	840	1	+ 8
135	185	235	285	335	435	535	635	835	1	+ 7
130	180	230	280	330	430	530	630	830	1	+ 6
125	175	225	275	325	425	525	625	825	1	+ 5
120	170	220	270	320	420	520	620	820	1	+ 4
115	165	215	265	315	415	515	615	815	1	+ 3
110	160	210	260	310	410	510	610	810	1	+ 2
105	155	205	255	305	405	505	605	805	1	+ 1
100	150	200	250	300	400	500	600	800	1	0
95	145	195	245	295	395	495	595	795	1	- 1
90	140	190	240	290	390	490	590	790	1	- 2
85	135	185	235	285	385	485	585	785	1	- 3
80	130	180	230	280	380	480	580	780	1	- 4
75	125	175	225	275	375	475	575	775	1	- 5
70	120	170	220	270	370	470	570	770	1	- 6
65	115	165	215	265	365	465	565	765	1	- 7
60	110	160	210	260	360	460	560	760	1	- 8
55	105	155	205	255	355	455	555	755	1	- 9
50	100	150	200	250	350	450	550	750	1	-10
75	100	125	150	175	225	275	325	425	2	+10
72.5	97.5	122.5	147.5	172.5	222.5	272.5	322.5	422.5	2	+ 9
70	95	120	145	170	220	270	320	420	2	+ 8
67.5	92.5	117.5	142.5	167.5	217.5	267.5	317.5	417.5	2	+ 7
65	90	116	140	165	215	265	315	415	2	+ 6
62.5	87.5	112.5	137.5	162.5	212.5	262.5	312.5	412.5	2	+ 5
60	85	110	135	160	210	260	310	410	2	+ 4
57.5	82.5	107.5	132.5	157.5	207.5	257.5	307.5	407.5	2	+ 3
55	80	105	130	155	205	255	305	405	2	+ 2
52.5	77.5	102.5	127.5	152.5	202.5	252.5	302.5	402.5	2	+ 1
50	75	100	125	150	200	250	300	400	2	0
47.5	72.5	97.5	122.5	147.5	197.5	247.5	297.5	397.5	2	- 1
45	70	95	120	145	195	245	295	395	2	- 2
42.5	67.5	92.5	117.5	142.5	192.5	242.5	292.5	392.5	2	- 3
40	65	90	115	140	190	240	290	390	2	- 4
37.5	62.5	87.5	112.5	137.5	187.5	237.5	287.5	387.5	2	- 5
35	60	85	110	135	185	235	285	385	2	- 6
32.5	57.5	82.5	107.5	132.5	182.5	232.5	282.5	382.5	2	- 7
30	55	80	105	130	180	230	280	380	2	- 8
27.5	52.5	77.5	102.5	127.5	177.5	227.5	277.5	377.5	2	- 9
25	50	75	100	125	175	225	275	375	2	-10
50	66.7	83.3	100	116.7	150	183.3	216.7	283.3	3	+10
48.3	65	81.7	98.3	115	148.3	181.7	215	281.7	3	+ 9
46.7	63.3	80	96.7	113.3	146.7	180	213.3	280	3	+ 8
45	61.7	78.3	95	111.7	145	178.3	211.7	278.3	3	+ 7
43.3	60	76.7	93.3	110	143.3	176.7	210	276.7	3	+ 6
41.7	58.3	75	91.7	108.3	141.7	175	208.3	275	3	+ 5
40	56.7	73.3	90	106.7	140	173.3	206.7	273.3	3	+ 4
38.3	55	71.7	88.3	105	138.3	171.7	205	271.7	3	+ 3
36.7	53.3	70	86.7	103.3	136.7	170	203.3	270	3	+ 2
35	51.7	68.3	85	101.7	135	168.3	201.7	268.3	3	+ 1
33.3	50	66.7	83.3	100	133.3	166.7	200	266.7	3	0
31.7	48.3	65	81.7	98.3	131.7	165	198.3	265	3	- 1
30	46.7	63.3	80	96.7	130	163.3	196.7	263.3	3	- 2
28.3	45	61.7	78.3	95	128.3	161.7	195	261.7	3	- 3
26.7	43.3	60	76.7	93.3	126.7	160	193.3	260	3	- 4
25	41.7	58.3	75	91.7	125	158.3	191.7	258.3	3	- 5
23.3	40	56.7	73.3	90	123.3	156.7	190	256.7	3	- 6
21.7	38.3	55	71.7	88.3	121.7	155	188.3	255	3	- 7
20	36.7	53.3	70	86.7	120	153.3	186.7	253.3	3	- 8
18.3	35	51.7	68.3	85	118.3	151.7	185	251.7	3	- 9
16.7	33.3	50	66.7	83.3	116.7	150	183.3	250	3	-10

Figure 10

Motor Load Indicators

Primary Current for Secondary Current of 5 Amperes										Primary Turns	Secondary Turns
100/5 Ratio	150/5 Ratio	200/5 Ratio	250/5 Ratio	300/5 Ratio	400/5 Ratio	500/5 Ratio	600/5 Ratio	800/5 Ratio			
35	47.5	60	72.5	85	110	135	160	210		4	+8
33.7	46.2	58.7	71.2	83.7	108.7	133.7	158.7	208.7		4	+7
32.5	45	57.5	70	82.5	107.5	132.5	157.5	207.5		4	+6
31.2	43.7	56.2	68.7	81.2	106.2	131.2	156.2	206.2		4	+5
30	42.5	55	67.5	80	105	130	155	205		4	+4
28.7	41.2	53.7	66.2	78.7	103.7	128.7	153.7	203.7		4	+3
27.5	40	52.5	65	77.5	102.5	127.5	152.5	202.5		4	+2
26.2	38.7	51.2	63.7	76.2	101.2	126.2	151.2	201.2		4	+1
25	37.5	50	62.5	75	100	125	150	200		4	0
23.7	36.2	48.7	61.2	73.7	98.7	123.7	148.7	198.7		4	-1
22.5	35	47.5	60	72.5	97.5	122.5	147.5	197.5		4	-2
21.2	33.7	46.2	58.7	71.2	96.2	121.2	146.2	196.2		4	-3
20	32.5	45	57.5	70	95	120	145	195		4	-4
18.7	31.2	43.7	56.2	68.7	93.7	118.7	143.7	193.7		4	-5
17.5	30	42.5	55	67.5	92.5	117.5	142.5	192.5		4	-6
26	36	46	56	66	86	106	126	166		5	+6
25	35	45	55	65	85	105	125	165		5	+5
24	34	44	54	64	84	104	124	164		5	+4
23	33	43	53	63	83	103	123	163		5	+3
22	32	42	52	62	82	102	122	162		5	+2
21	31	41	51	61	81	101	121	161		5	+1
20	30	40	50	60	80	100	120	160		5	0
19	29	39	49	59	79	99	119	159		5	-1
18	28	38	48	58	78	98	118	158		5	-2
17	27	37	47	57	77	97	117	157		5	-3
16	26	36	46	56	76	96	116	156		5	-4
15	25	35	45	55	75	95	115	155		5	-5
20.8	29.2	37.5	45.8	54.2	70.8	87.5	104.2	137.5		6	+5
20	28.3	36.7	45	53.2	70	86.7	103.3	136.7		6	+4
19.2	27.5	35.8	44.2	52.5	69.2	85.8	102.5	135.8		6	+3
18.3	26.7	35	43.3	51.7	68.3	85	101.7	135		6	+2
17.5	25.8	34.2	42.5	50.8	67.5	84.2	100.8	134.2		6	+1
16.7	25	33.3	41.7	50	66.7	83.3	100	133.3		6	0
15.8	24.2	32.5	40.8	49.2	65.8	82.5	99.2	132.5		6	-1
15	23.3	31.7	40	48.3	65	81.7	98.3	131.7		6	-2
14.2	22.5	30.8	39.2	47.5	64.2	80.8	97.5	130.8		6	-3
13.3	21.7	30	38.3	46.7	63.3	80	96.7	130		6	-4
17.1	24.3	31.4	38.6	45.7	60	74.3	88.6	117.1		7	+4
16.4	23.6	30.7	37.9	45	59.3	73.6	87.9	116.4		7	+3
15.7	22.9	30	37.1	44.3	58.6	72.9	87.1	115.7		7	+2
15	22.1	29.3	36.4	43.6	57.9	72.1	86.4	115		7	+1
14.3	21.4	28.6	35.7	42.9	57.1	71.4	85.7	114.3		7	0
13.6	20.7	27.9	35	42.1	56.4	70.7	85	113.6		7	-1
12.9	20	27.1	34.3	41.4	55.7	70	84.3	112.4		7	-2
12.1	19.3	26.4	33.6	40.7	55	69.3	83.6	112.2		7	-3
11.4	18.6	25.7	32.9	40	54.3	68.6	82.9	111.4		7	-4
14.4	20.7	26.9	33.1	39.4	51.9	64.3	76.9	101.9		8	+3
13.8	20.1	26.3	32.5	38.8	51.3	63.7	76.3	101.3		8	+2
13.1	19.4	25.6	31.8	38.1	50.6	63.1	75.6	100.6		8	+1
12.5	18.8	25	31.2	37.5	50	62.5	75	100		8	0
11.9	18.2	24.4	30.6	36.9	49.4	61.9	74.4	99.4		8	-1
11.2	17.6	23.8	30	36.3	48.8	61.2	73.8	98.8		8	-2
10.6	16.9	23.1	24.4	35.6	48.1	60.6	73.1	98.1		8	-3
12.8	18.3	23.9	29.4	35	46.1	57.2	68.3	90.5		9	+3
12.2	17.7	23.3	28.9	34.4	45.5	56.7	67.8	90		9	+2
11.7	17.2	22.8	28.3	33.9	45	56.1	67.2	89.4		9	+1
11.1	16.7	22.2	27.8	33.3	44.4	55.6	66.7	88.9		9	0
10.5	16.1	21.7	27.2	32.8	43.9	55	66.1	88.4		9	-1
10	15.5	21.1	26.6	32.2	43.3	54.4	65.5	87.8		9	-2
9.4	15	20.5	26.1	31.7	42.8	53.9	65	87.2		9	-3
11.5	16.5	21.5	26.5	31.5	41.5	51.5	61.5	81.5		10	+3
11	16	21	26	31	41	51	61	81		10	+2
10.5	15.5	20.5	25.5	30.5	40.5	50.5	60.5	80.5		10	+1
10	15	20	25	30	40	50	60	80		10	0
9.5	14.5	19.5	24.5	29.5	39.5	49.5	59.5	79.5		10	-1
9	14	19	24	29	39	49	59	79		10	-2
8.5	13.5	18.5	23.5	28.5	39.5	48.5	58.5	78.5		10	-3

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VI: Ac Ammeter Type

(1) This is a standard moving-iron ammeter with a full-scale rating of 5 amperes. The standard scale legend is "PERCENT MOTOR LOAD-CURRENT." The current transformer is selected from table (Figure 10) using the formula:

(g)

$$I_{pri} = A \times 1.15$$

where I_{pri} = current transformer primary current
 A = motor full load current

(2) Ammeters can be marked at extra cost for percent motor horsepower assuming constant voltage and frequency. The legend would then be PERCENT HORSEPOWER. In such cases the current transformer is selected by the above formula. The scale must be specially drawn to relate to the motor manufacturers' performance data. Usually the published data does not include motor currents at all loads, so these must be calculated from formula (e), Paragraph IV(3).

(3) From the percent horsepower scale it is a small step to calibrate in actual horsepower. Here special legends are more the rule — such as "MAIN DRIVE HORSEPOWER," "HORSEPOWER-PUMP NO. 6" and the like. The overload range is not limited to 150%. Except for switchboard instruments, the only limitation is that the current be 5 amperes on the instrument at the highest horsepower shown on the instrument scale.

(4) The current transformer is selected from the table in Figure 10 using the formula:

(h)

$$I_{(pri)} = \frac{A \times hp (fs)}{hp}$$

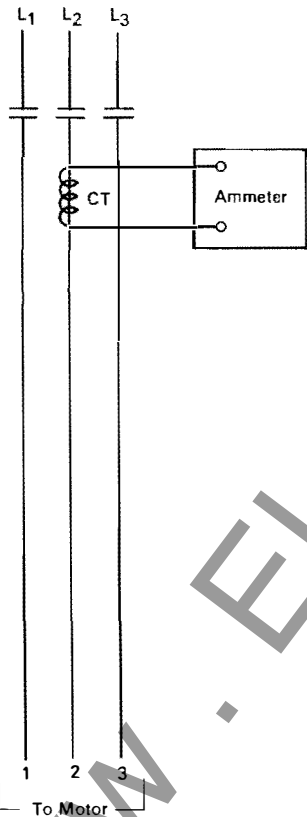
where I_{pri} = current transformer primary current
 A = full load current
 $hp (fs)$ = maximum horsepower on scale
 hp = rated horsepower

(5) If it is not possible to get information to 6/4 load from the motor manufacturer this information may be estimated by extrapolating curves of available data using figures 4, 5, 6 and 7 as a general guide.

On two-speed motors a single ammeter is connected to two current transformers. Each is selected by formula (g) or (h) for the full-load current at each speed.

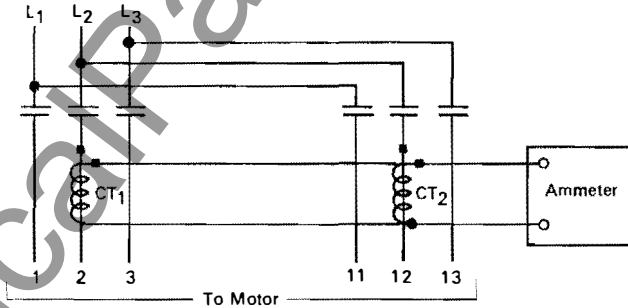
(6) Before deciding to use an ammeter on a two-speed motor, make sure that the current drawn by the motor increases reasonably as the load increases. On some designs the power factor changes so greatly with load, especially on the low-speed connection, that an ammeter reading is meaningless. In these cases a wattmeter or in-phase ammeter should be used.

(7) Three and four-speed motors have combinations of two windings of fixed or reconnectable types. On these the current-to-load relationships are so different at different speeds that an ammeter is worthless as a load indicator. Again, the in-phase ammeter or the wattmeter should be used.



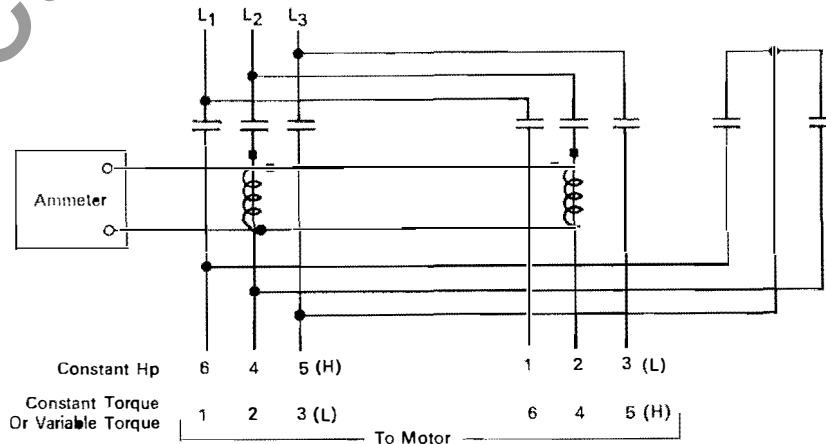
Ammeter Connections For Single-Speed Ac Induction Motors

Figure 11



Ammeter Connections For Two-Speed Two-Winding Ac Induction Motors

Figure 12



Ammeter Connections For Two-Speed Single-Winding Ac Induction Motor (Letters H and L Indicate High and Low Speeds)

Figure 13

Motor Load Indicators

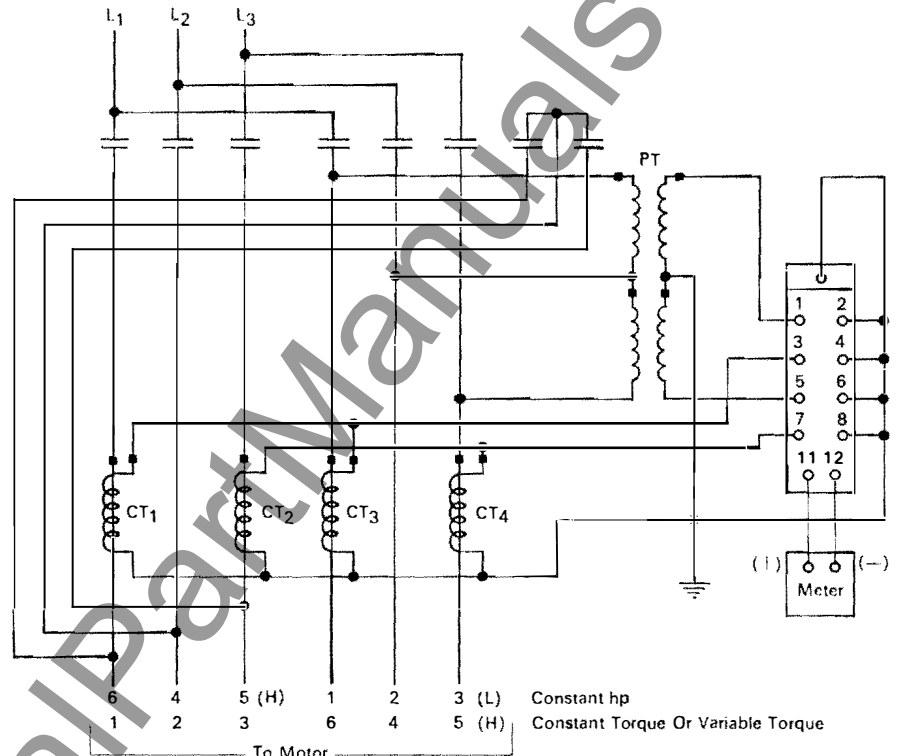
VII: Ac Wattmeter Type

(1) In Figure 2 it was shown that the watts drawn by a motor are the best measure of a motor load. Watt measurement will give a reasonably linear horsepower scale down to only a few percent of rated horsepower. Wattmeters of the switchboard type, except Edgewise Type 252, may be either self-contained or furnished with separately mounted transducers. The Type 252 and all panel meter types are made with the separate transducer only. Usually there is an advantage to the separate transducer in that it may be located in the motor control structure and only two wires need be run to the instrument in the operator's console.

The standard legend for the wattmeter type indicator is "PERCENT MOTOR LOAD-POWER". As with ammeters, the wattmeters may be supplied calibrated to a specific motor performance—in which case they normally have a legend "PERCENT HORSEPOWER"; or they may be calibrated in actual horsepower with such special legends as "HORSEPOWER PUMP NO. 6" or "MAIN DRIVE HORSEPOWER".

(2) Polyphase Wattmeter

An induction motor has reasonably well balanced current when line voltages are balanced. Therefore, a single phase wattmeter is usually adequate for motor power measure-



Connections For A Two-Element Polyphase Wattmeter To A Two-Speed Ac Induction Motor

Figure 15

ment. There are some critical jobs where one might prefer to use a polyphase wattmeter.

For the standard polyphase wattmeter with two current coils and two potential coils the basic scale formula is:

$$(i) \quad W(fs) = W(sc) \times r(ct) \times r(pt)$$

where $W(fs)$ = Maximum watts on scale

$W(sc)$ = Self-contained rating of wattmeter

= 1000 W for 5 A, 120 V

= 2000 W for 5 A, 240 V

= 4000 W for 5 A, 480 V

$r(ct)$ = Current transformer ratio

$r(pt)$ = Potential transformer ratio

So, for the motor load indicator with a scale of 150% of motor full load watts and a two-element transducer with a self-contained rating of 1000 watts the current transformer works out to be:

$$(j) \quad I(ri) = r(ct) \times 5 = \frac{W(fs)}{W(sc) \times r(pt)} \times 5 = \frac{1.5 \times W \times 5}{r(pt) \times 1000}$$

where $I(ri)$ = Current transformer primary current
 W = Full load watts of motor

See formulas (a) and (b) in Section IV(3) to calculate W .

This simplifies to:

For 460 Volt motor on 480 Volt system using 4:1 potential transformers and 120 Volt transducer or 480 Volt wattmeter where available.

$$(k) \quad I(ri) = \frac{W}{533}$$

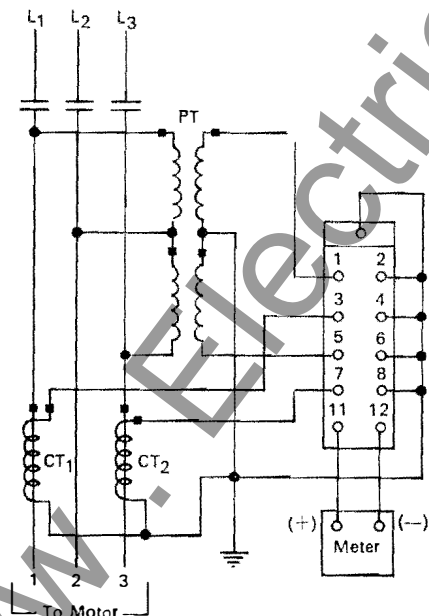
For 230 Volt motor on 240 volt system using 2:1 potential transformers with the standard 120 volt transducer or the 230 volt transducer with no potential transformer

$$(l) \quad I(ri) = \frac{W}{266}$$

For 575 volt motor in 600 volt system using 5:1 potential transformers and 120 volt transducer

$$(m) \quad I(ri) = \frac{W}{666}$$

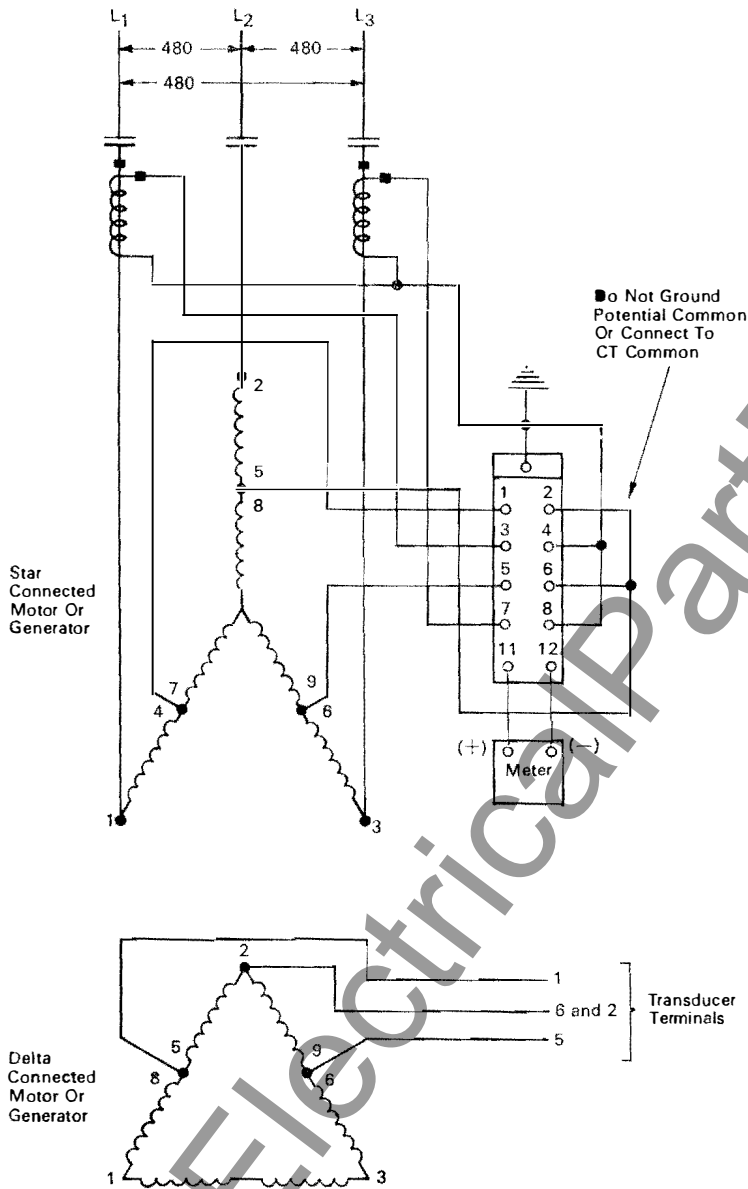
Transducers may be separately mounted or built into self-contained wattmeters. The same formulas apply for the dynamometer wattmeters, 100° switchboard type.



Connections For A Two-Element Polyphase Wattmeter To A Single-Speed Ac Induction Motor

Figure 14

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VII: Ac Wattmeter Type
(Continued)

(3) Single phase wattmeters

Within the accuracies required on motor load indicators the single-phase wattmeter is generally adequate for polyphase motors. Voltages on industrial circuits are usually reasonably balanced. Currents on polyphase motors are closely balanced by design when the voltages are balanced. This makes the polyphase watts a simple multiple of single phase watts.

Motors are connected 3-wire with the neutral inaccessible. The line current at unity power factor is not in phase with the available voltage as required for watt measurement. To get a current and a voltage in phase, a double primary current transformer is used, so connected to reverse one current and add it vectorially to the other. The resultant is in phase with an available voltage.

This connection requires that two motor leads be passed in opposite directions through the "hole" in a Type ECI current transformer. The basic formula (i) is the same as that for the 2-element wattmeter except that the self-contained ratings are:

- W (sc) = Self-contained rating of wattmeter
- = 500 W for 5 A, 120 V
- = 1000 W for 5 A, 240 V
- = 2000 W for 5 A, 480 V

This makes the current transformer primary current one-half that for the equivalent polyphase two-element wattmeter. For 460 volt motor on 480 volt system using 4:1 potential transformers or 480 volt transducer

$$(n) I(pri) = \frac{W}{266}$$

For 230 volt motor on 240 volt system with 2:1 potential transformer or 240 volt transducer.

$$(o) I(pri) = \frac{W}{133}$$

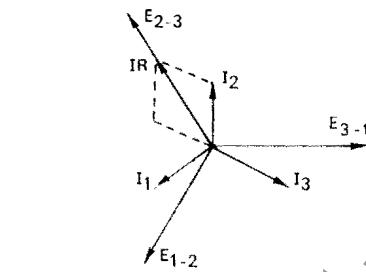
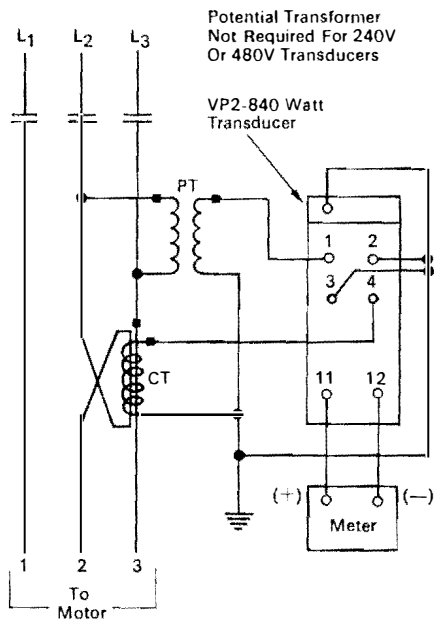
For 575 Volt motor with 5:1 potential transformer

$$(p) I(pri) = \frac{W}{333}$$

Connections For A 240-Volt Two-Element Polyphase Wattmeter To A 480-Volt Single-Speed Induction Motor (No Potential Transformer Required)

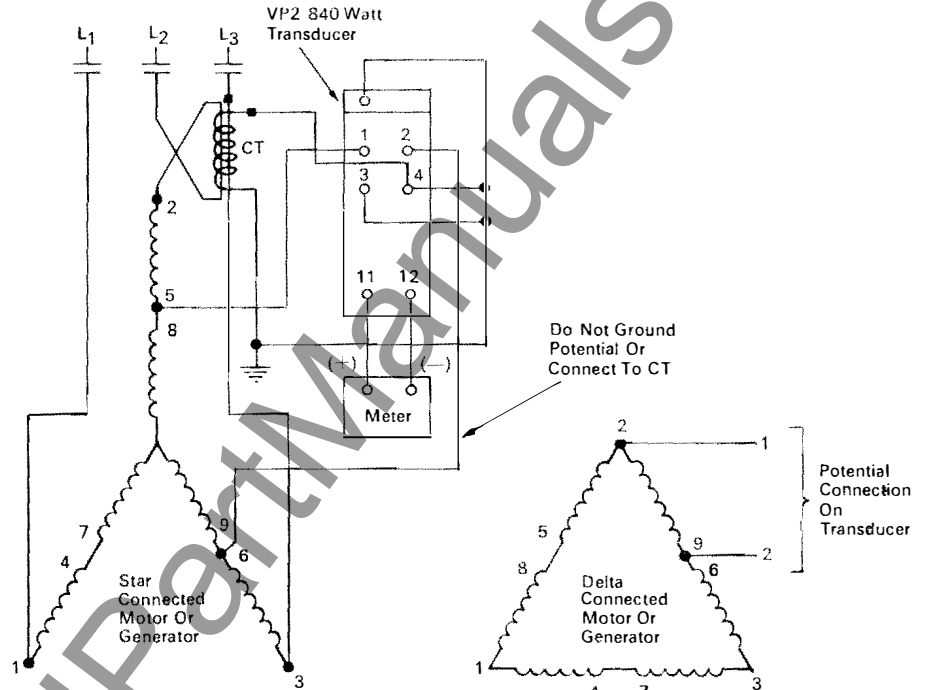
Figure 16

Motor Load Indicators



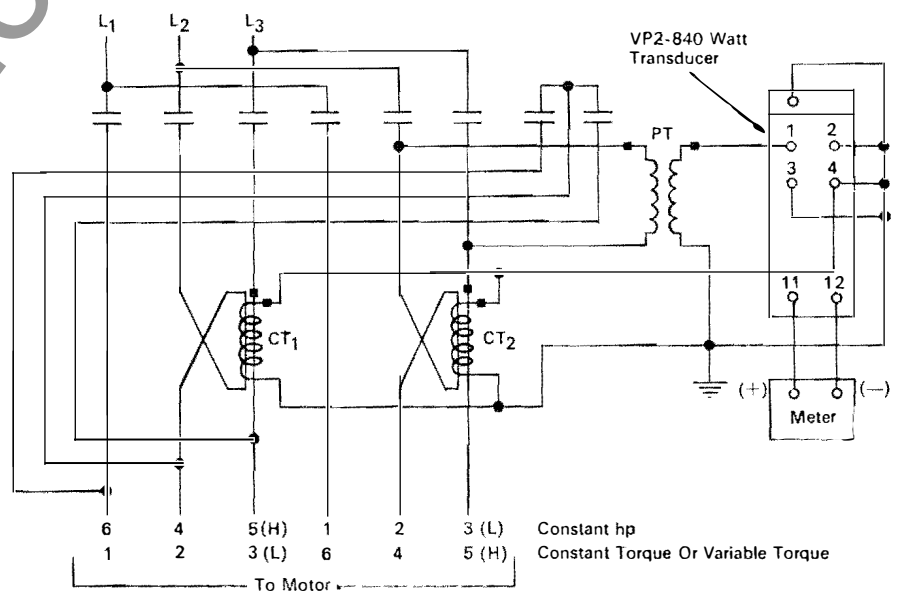
Connections For A Single-Element Single-Phase Wattmeter To a Three-Phase Single-Speed Ac Induction Motor Using One Current Transformer With Two Primary Windings

Figure 17



Connections For A 480-Volt Three-Phase Motor With A 240-Volt Single-Phase Watt Transducer (No Potential Transformer Required)

Figure 18



Connections For A Single-Element Single-Phase Wattmeter To A Three-Phase Two-Speed Ac Induction Motor Using Current Transformers, Each With Two Primary Windings (Potential Transformers Not Required With 240 Or 480 Volt Transducers)

Figure 19

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VIII: In-Phase Current Type

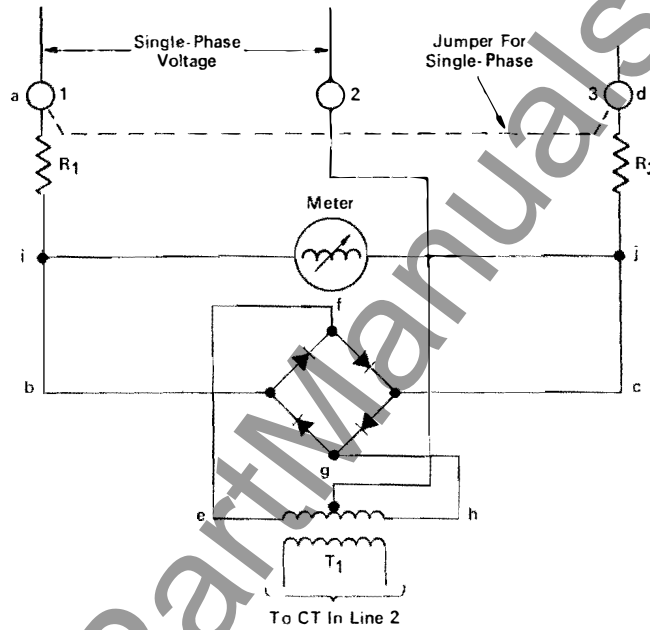
(1) This motor load indicator represents the best compromise between accuracy, ease-of-application and price. It measures that portion of the motor current which is proportional to power. It can be connected for single-phase or polyphase, 120, 240 or 480 volts, so only one device will serve most commercial applications.

(2) Motor currents break down into three basic components; (1) loss which increases slightly with load; (2) work which is proportional to load and (3) magnetizing current which is disproportionately high at light loads. As is shown in Figure 2, the motor current is not a good indicator of load much below 50% of load. However, the component (2) above is directly proportional to load so, if measurable, would be ideal. The component (1), loss, is relatively small and constant, so it could be included without degrading the measurement unduly. These combine simply as input power which ordinarily one would measure with a wattmeter.

(3) Power is $\sqrt{3} EI \cos \theta$. If one considers the voltage as constant, a normal condition on industrial power circuits, the power is proportional to $I \cos \theta$. This is the energy component of the current (1) plus (2). The magnetizing component (3) is 90 degrees out of phase with voltage, the cosine of 90° is 0 so the power is 0. Thus any instrument which will read the in-phase or power component ($I \cos \theta$) of current will be an excellent motor load indicator.

(4) A network has been developed consisting of a transformer, a ring modulator and several series resistors. The circuit is shown in Figure 20.

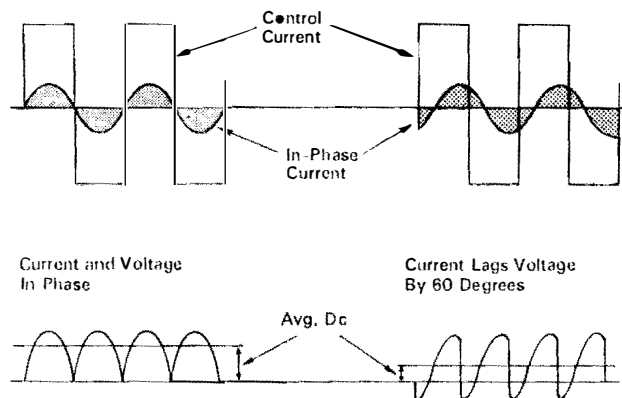
(5) In a ring modulator circuit four diodes are connected as shown. The line voltage causes control currents to flow through R1 and R2 and the instantaneous direction of these currents cause the diodes to conduct or not to conduct. This flow is balanced so it does not cause a current to flow in the meter element. An additional current is supplied by T1 proportional to line current. This is passed by the diodes which are in a conducting state, "turned on" in a sense by the voltage. This additional current, which is registered by the meter, is proportional to the line current modified by the phase angle between it and the voltage. Specifically it is the effective dc value of the asymmetrical wave shown in Figure 21. Therefore the device can be calibrated to read $I \cos \theta$ or the in-phase component of current.



Voltage causes proportional control current to circulate in a, b, c, d.
 Load current causes proportional current to circulate in e, f, g, h.
 Meter current proportional to in-phase component of load current circulates b, i, j, c.

In-Phase Ammeter Single-Phase Schematic

Figure 20

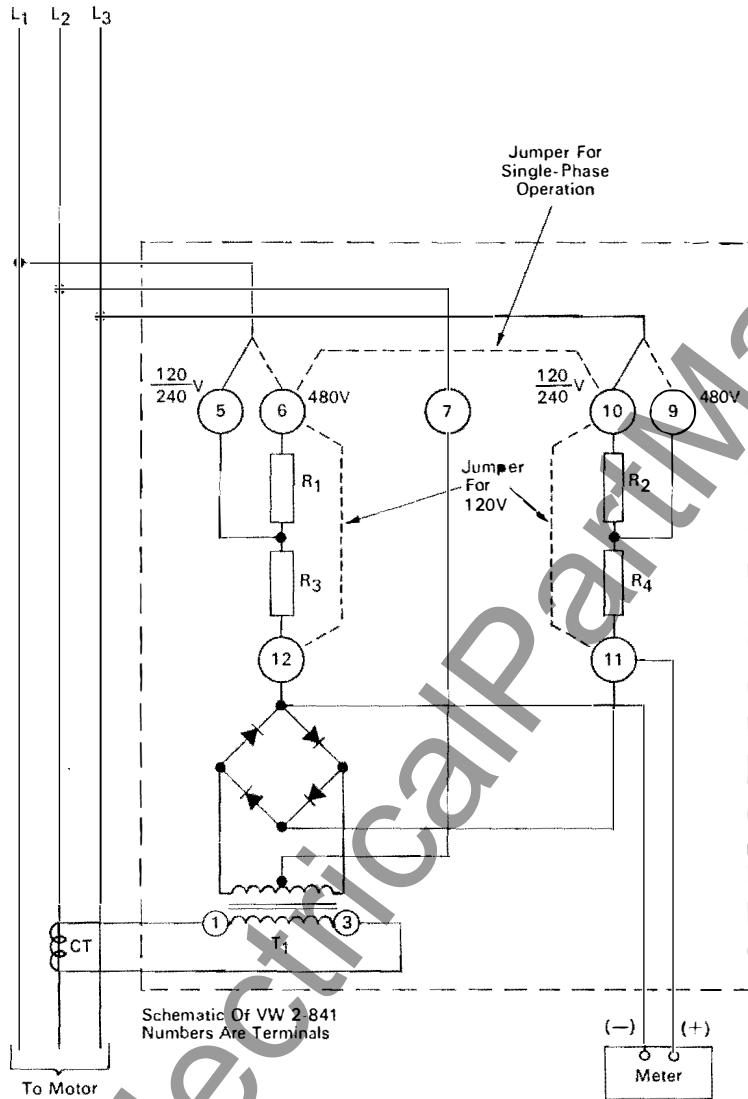


Rectified output to meter exaggerated for clarity.

In-Phase Ammeter Control And Output Currents

Figure 21

Motor Load Indicators



Transducer Connections

	Current Transformer	Meter	Jumpers	Line
120 V, 3 Ph, 3 W	1, 3	11, 12	6-12, 10-11	7, 5, 9
240 V, 3 Ph, 3 W	1, 3	11, 12	None	7, 5, 9
480 V, 3 Ph, 3 W	1, 3	11, 12	None	7, 6, 10
120 V, 1 Ph, 2 W	1, 3	11, 12	6-10, 6-12, 10-11	7, 5, 9
240 V, 1 Ph, 2 W	1, 3	11, 12	6-10	7, 5, 9
480 V, 1 Ph, 2 W	1, 3	11, 12	6-10	7, 6, 10

In-Phase Current Type VW 2-841 Motor Load Indicator With Separate Transducer - Single-Phase Or Three-Phase, 120, 240 Or 480 Volts

Figure 22

(6) As with other motor load indicators, the standard in-phase current type is rated 5 amperes full scale. However, here the power factor must be accounted for, so we have taken a nominal 87 percent at full load. This results in an instrument which reads full scale of 150 percent load when the in-phase current is 4.3 amperes. At 100 percent load this is 2.86 in-phase amperes.

Therefore, for motors with a nominal 87 percent full load power factor:

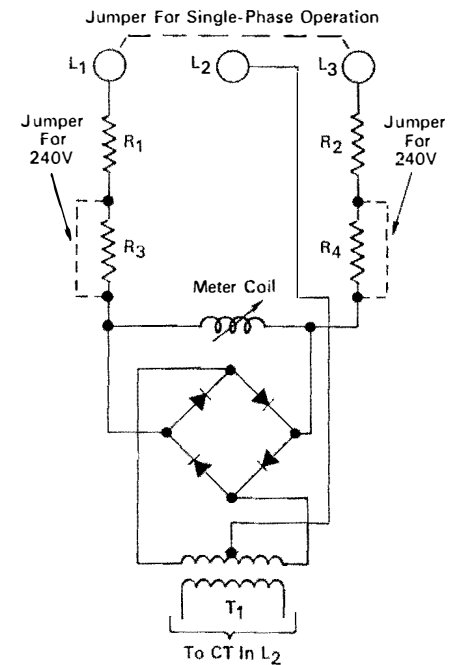
$$(q) I_{pri} = A \times 1.5$$

For any other power factor

$$(r) I_{pri} = \frac{A \times 1.3}{Pf \text{ (full load)}}$$

(7) The standard legend is "PERCENT MOTOR LOAD-POWER." Where motor performance data is furnished the dial can be marked "PERCENT HORSEPOWER" or the scale can be in actual horsepower with any appropriate legend.

(8) The in-phase current motor load indicator is supplied with a separate VW2-841 transducer, except for the NC-371 and RC-371 types which are available self-contained.



Self-Contained In-Phase Current Type Motor Load Indicator Type RC-371 Or NC-371 Only - Single Or Three-Phase, 240 Or 480 Volts

Figure 23

Westinghouse



IX: Adjustable Speed Drives

(1) On those types of ac adjustable speed drives which use a dc motor for output torque, the problem is as discussed under dc motors where load values proportional to torque are desired. Where load indication is to be proportional to horsepower it is best to simply measure the input to the driving motor or rectifier using any of the conventional ac load indicators, amperes, polyphase watt, single phase watt or in-phase current. A study of performance curves of the individual drives will show if accuracy is within tolerable limits. There may be a fair discrepancy between ac inputs, for example, at a single horsepower level depending on whether the drive is developing low torque at high speed or high torque at low speed. If the differences are too great, there remains only the dc wattmeter, which is available in the 100 degree switchboard instrument only.

(2) See Section X on dc motors for load indicators based on torque. These are the dc ammeter type, measuring armature current. They are applicable to adjustable speed drives of the adjustable voltage, the reactor-controlled rectifier, and the silicon controlled rectifier type.

(3) On the eddy current adjustable speed drives (Westinghouse Magnaflow) there is no valid application of conventional motor load indicators except where indications of motor inputs are of value. This would be the case where the coupling is being operated fully excited during the period that the load is to be monitored. Under partial excitation, when the clutch is slipping, the motor load indicator cannot discriminate between the slip loss of the clutch and the power delivered to the load.

(4) The measurement of power into wound rotor motors is not meaningful in terms of load whenever variable secondary resistance

is used for speed control. For any one value of secondary resistance, or when secondary resistance is used for starting only, a conventional motor load indicator may be selected as for any ac motor.

(5) There is (Westinghouse Rectiflow) a combination of wound rotor motor with slip rectifiers in the secondary feeding into a dc motor on a common shaft. These are constant horsepower machines with essentially the same efficiencies at all speeds. Any ac motor load indicator may be used ahead of this drive. Power factor is close to that of a corresponding size ac motor.

(6) Variable frequency drives, if single motor, might best be monitored for horsepower at the ac input to the control unit. At constant volts per hertz ac motors have constant torque capability over a range of frequencies and it is usual that the load be related to torque. Here, the ac ammeter gives the closest correlation. There will be some pointer vibration at frequencies below 25 Hz but performance will be uniformly good from there through the operating range of the drive. The selection of transformer primary is made as for the standard ac motor.

When it is necessary for the meter to respond to the horsepower of each motor on a multi-motor drive, single phase wattmeters should be used in the conventional connection with two motor leads, one reversed, through an ECI transformer. In the case of the 100 degree switchboard instrument, a standard dynamometer wattmeter should be used. For all others, a Hall generator wattmeter with VP2-840 transducer will be needed. Generally 30 Hz is the low frequency limit for rated accuracy. The high limit is usually within the operating range of the drive. This application should be negotiated with the factory.

Motor Load Indicators

X: Dc Motors

(1) The direct current motor is used for constant speed as well as adjustable speed drives. Speeds may be increased over the base speed by weakening the field. The torque will reduce proportionately so the machine horsepower remains constant. Speeds are decreased below base speed by reducing the armature voltage. The torque now remains constant so the horsepower capability decreases. In each case the current in the armature is the load limiting factor. Thus, an ammeter is an ideal indicator of dc motor loads under all operating conditions. The ammeter would properly be marked "PERCENT MOTOR LOAD-CURRENT".

(2) To indicate loads proportional to horsepower, the ammeter may be used only with a motor utilizing field control. Where armature voltage is varied, a wattmeter would be needed. Dc wattmeters are made in 100 degree switchboard types only. The proper legend would be "PERCENT MOTOR LOAD-POWER" or "HORSEPOWER". Motor performance data is required with the order for laying out these scales.

A standard 50 mV Dc ammeter is the basic instrument used with an external shunt.

(s) Shunt Rating = A x 1.5

Odd ratings of shunts are difficult to get, so if a 50 mV shunt is not available with the correct current rating there are three solutions:

(3) The preferred method is to use a standard 50 mV motor load indicator with a 100 mV shunt. Select the shunt with the next higher current rating than the motor full load current. Insert an adjustable resistor in one instrument lead. The resistor loss is a small portion of a watt, so the smallest available slide wire or wirewound potentiometer may be used—a resistance approximately 1.5 times the instrument terminal resistance is adequate.

Terminal resistance of load indicators 50 mV ammeter types

180° Circular Scale KX-231	100 ohms
250° Circular Scale KX-241, KX-261	20 ohms
100° Circular Scale KX-221, KX-251	71.4 ohms
Edgewise VX-, HX-252	50.0 ohms
20/20 Panel	50.0 ohms
Foundation	50.0 ohms
Conventional N-, R-351, -371	3.85 ohms
Recorder Type 44	.25 ohms

Figure 24

With a test millivoltmeter connected to the shunt, put a load on the motor as near as possible to full load and adjust the resistor so the motor load indicator reads correctly in terms of percent of full load current. It will then read correctly at all values. Of course, the same calibration could be performed without the motor by using any separate source of dc current.

(4) If a fixed resistor is preferred the value is determined by:

$$(t) R = \frac{3 \times A \times R_i}{\text{Shunt rating (Amps)}} - R_i$$

where R = fixed resistance value
A = full load current of motor
R_i = instrument terminal resistance

If it is necessary to correct for instrument lead resistance, subtract the difference between the actual lead resistance and .005 from the resistance value calculated.

This is likely to be the case with recorders.

(5) At the added expense of special instruments, either the adjustable potentiometer or the fixed resistor can be built into the instrument case. The fixed resistor is priced as an "intermediate rating" and the potentiometer as "calibrating rheostat on base" in the modification price lists.

(6) In some cases it is possible to stay with the lower priced 50 mV shunt for odd values. Select a 50 mV shunt with the next higher current rating: Specify the load indicator as similar to the standard style except with a rating:

$$(u) mV = \frac{A \times 1.5 \times 50}{\text{Available shunt rating}}$$

This method should be used only if shunts are large or if large quantities of meters are involved. It always means a special sensitivity instrument. It is necessary to check the factory because not all types of instruments can be built with the necessary characteristics.

Popular standard shunt ampere ratings, 50 or 100 mV drop

2	20	150
3	25	200
4	30	250
5	50	300
7.5	60	400
8	75	500
10	80	600
15	100	750

For larger ratings see Price List 43-820.

Figure 25

XI: Recorders

Type K-44 switchboard mounting or P-44 portable strip chart recorders can be used as motor load indicators. Order recorders from Price List 43-400 using the ratings corresponding to the indicating type motor load indicators. Charts will be 0-150. The legend will be "PERCENT MOTOR LOAD". Recorders calibrated in horsepower generally are not practical except where a chart exists for the correct full scale horsepower.

Westinghouse



XII: Examples

(1) A motor rated 50 hp, 460 volt, 1775 rpm, drives a metal cutting saw. Select a percent motor load indicator, scale 0-150 percent.

Load	Current	Power Factor	Efficiency
1/2	...	87	91.0
3/4	...	84.5	91.5
Full	59.0	77	91.0

Ammeter type PERCENT MOTOR LOAD-CURRENT will use a transformer with a primary current per formula (g) Section VI (1).

$$I_{pri} = A \times 1.5 = 59.0 \times 1.5 = 88.3$$

From the table in figure 10 we find a primary current of 88.3 using the 250:5 transformer with 3 primary turns and 3 added secondary turns.

The nature of the job is such that accurate readings are needed on light cuts in the area of .2 load. Examination of scales in Figure 1 show that the watt measuring device would give more than twice the readability of an ammeter in this area.

So deciding on a single phase wattmeter PERCENT MOTOR LOAD-POWER we select the current transformer from formula (n)

$$I_{(pri)} = \frac{W}{266}$$

Formula (a) tells us

$$W = \frac{hp \times 746}{eff} = \frac{50 \times 746}{.91} = 41000$$

$$I_{(pri)} = \frac{41000}{266} = 154 \text{ amperes}$$

From the table in figure 10 we select a 150:5 Type ECI transformer with 1 primary turn and one added secondary turn.

or

The in-phase ammeter PERCENT MOTOR LOAD-POWER will give an equally good scale with essentially the same accuracy if voltage is steady.

Now the current transformer is selected by formula (q)

$$I_{(pri)} = A \times 1.5 = 88.3$$

This is the same as for the ammeter.

The Type A scale should be used as the instrument will be read at all values.

(2) A 40 hp, 1180 rpm 460 volt, TEFC motor is being used on a pulverizer. There is a thermal limit on the machine making actual horsepower loads of interest. The scale is to be 0-60 HORSEPOWER. There is likely to be voltage unbalance, so a polyphase watt-

meter is preferred with a Type "B" scale. The motor manufacturer cannot supply test data beyond that shown here

Load	Current	Power Factor	Efficiency
1/2	...	79	89
3/4	...	86	90
Full	47	88.5	89.5

It is necessary therefore to extrapolate the efficiency data per Sec IV (4) as shown in Figure 26.

From formula (a) in IV(3) determine watts input for each increment of HP.

$$W = \frac{hp \times 746}{eff.}$$

On the order for the motor load indicator specify:

Horsepower	Input Kilowatts
10	9.5
20	16.8
30	24.9
40	33.2
50	41.9
60	50.2

Or it is sufficient to specify only efficiency at each load increment. If efficiency is not known but current and power factor are known for each load increment, they may be specified instead of efficiency or input watts. It is always best to specify horsepower and corresponding input watts, - there is much much less chance of error.

The current transformer is selected from formula (k)

$$I_{(pri)} = \frac{W}{533} = \frac{33200}{533} = 62.4$$

This would require the 100:5 rated ECI transformer with two primary turns and five added secondary turns.

(3) A type 20/20 motor load indicator is required for a 15 hp shunt wound motor with a full load current of 52 amperes. The motor has speed control 2:1 by field weakening. The motor drives a fan with variable loads.

From Section X it is found that an ammeter is the best instrument for the job. The legend will be "PERCENT MOTOR LOAD" - CURRENT. The scale 0-150 percent. The Type B scale is preferred.

The shunt rating for use with a 50 mV instrument would be, from formula (s)

$$\text{Shunt Rating} = A \times 1.5 = 78$$

There are standard 50 mV shunts of 75 and 80 amperes, but these would introduce errors of 4% and 2 1/2% respectively. For a more accurate application, use a 100 mV shunt rated 80 amperes and select a series resistor for the instrument leads from the formula (t)

$$R = \frac{3 \times A \times R_i}{\text{Shunt rating} - R_i} = \frac{3 \times 52 \times 50}{80} - 50 = 47.5 \text{ ohms}$$

There is now a choice of buying a standard dc ammeter type load indicator and using a potentiometer of 60 or 100 ohms, or using a fixed resistor of 47.5 ohms, or ordering the meter with a special terminal resistance of 97.5 ohms, or ordering the meter with a built-in calibrating rheostat. These choices are described in Section X.

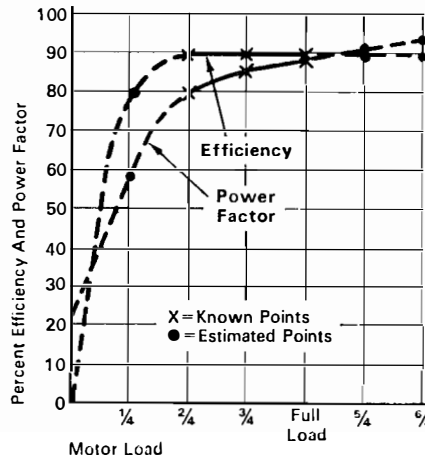


Figure 26

Motor Load Indicators

Condensed Application Table for Motor Load Indicators

Type	Standard Legend	Scale	CT Primary Amperes	Motor Data Required With Orders	CT's Required	Separate Transducer	Comments
Ac Motors							
Ammeter	Percent Motor Load-Current	A or B	A x 1.5	No	1	No	The lowest cost indicator. Accuracy at light loads is limited. Voltage variations introduce errors.
	Percent Horsepower	A or B	A x 1.5	Yes	1	No	
	Horsepower	Special	A at Max. Scale hp	Yes	1	No	
Wattmeter Polyphase 3 Phase	Percent Motor Load-Power	A or B	(575 V, W ÷ 666)	No	2	VP2-840	Best for adverse conditions of light load, unbalanced voltage, variable voltage and poor power factor. Relatively expensive.
	Percent Horsepower	A or B	(460 V, W ÷ 533)	Yes	2	VP2-840	
	Horsepower	Special	Calculate from formula j	Yes	2	VP2-840	
Wattmeter Single-Phase on 3 Phase Motor	Percent Motor Load-Power	A or B	(575 V, W ÷ 333)	No	1	VP2-840	The best economic choice for the complete range of loads with normal voltage balance and power factors.
	Percent Horsepower	A or B	(460 V, W ÷ 266)	Yes	1	VP2-840	
	Horsepower	Special	Calculate from formula j	Yes	1	VP2-840	
In-Phase Current Ammeter	Percent Motor Load-Power	A or B	for .87 pf, A x 1.5	No	1	*VW2-841	This type is the best economic choice for the complete range of loads where the voltages are constant and balanced. Permits stocking one unit for all voltages, single or polyphase.
	Percent Horsepower	A or B	for other pf: $\frac{A \times 1.3}{pf}$	Yes	1	*VW2-841	
	Horsepower	Special	A at max scale hp	Yes	1	*VW2-841	
DC Motors							
Ammeter	Percent Motor Load-Current Percent Horsepower (See Sect. X for limits)	A or B A or B	Calculate series resistors from formulas (s) (t) or (u)	No Yes	Shunt Shunt	No No	The best choice for all situations except where actual power readout is required.
Wattmeter	Percent Motor Load-Power Horsepower	A or B Special	..	Yes Yes	Shunt Shunt	No No	Used where dc measurements must be horsepower responsive on motors with armature control. Available as 100' switchboard instruments only.

A = Motor full load amperes
W = Motor full load watts
Pf = Motor full load Power Factor
SC = Self-contained rating of wattmeter or transducer

Motor Load Indicators

Further Information

For information on prices, dimensions, electrical characteristics etc. please refer to the catalog sections for the specific instrument types:

Type		Prices	Description	Dimensions Performance
Panel Instruments	20/20	PL 43-300	DB 43-320	AD 43-300
	Conventional	PL 43-300	DB 43-350	AD 43-300
	Foundation	PL 43-300	DB 43-370	AD 43-300
Switchboard Instruments	K-221	PL 43-200	DB 43-220	AD 43-200
	K-231	PL 43-200	DB 43-230	AD 43-200
	K-241	PL 43-200	DB 43-240	AD 43-200
	K-251	PL 43-200	DB 43-250	AD 43-200
	E-251	PL 43-200	DB 43-255	AD 43-200
	V, H-252	PL 43-200	DB 43-252	AD 43-200
	K-261	PL 43-200	DB 43-260	AD 43-200
Recorders	Type 44	PL 43-400	DB 43-440	DB 43-440 WD 43-440
	Type 45	PL 43-400	DB 43-450	DB 43-450
Transducers	Watt VP2-840		DB 43-860	AD 43-860
	In-phase current VW2-841		IL 43-841.8	AD 43-860
Current Transformers		PL 44-020	DB 44-112	DB 44-112