# Smaller and Lighter-A reboot on neutron detectors

## The Ludlum Model 30-7B

November 2018

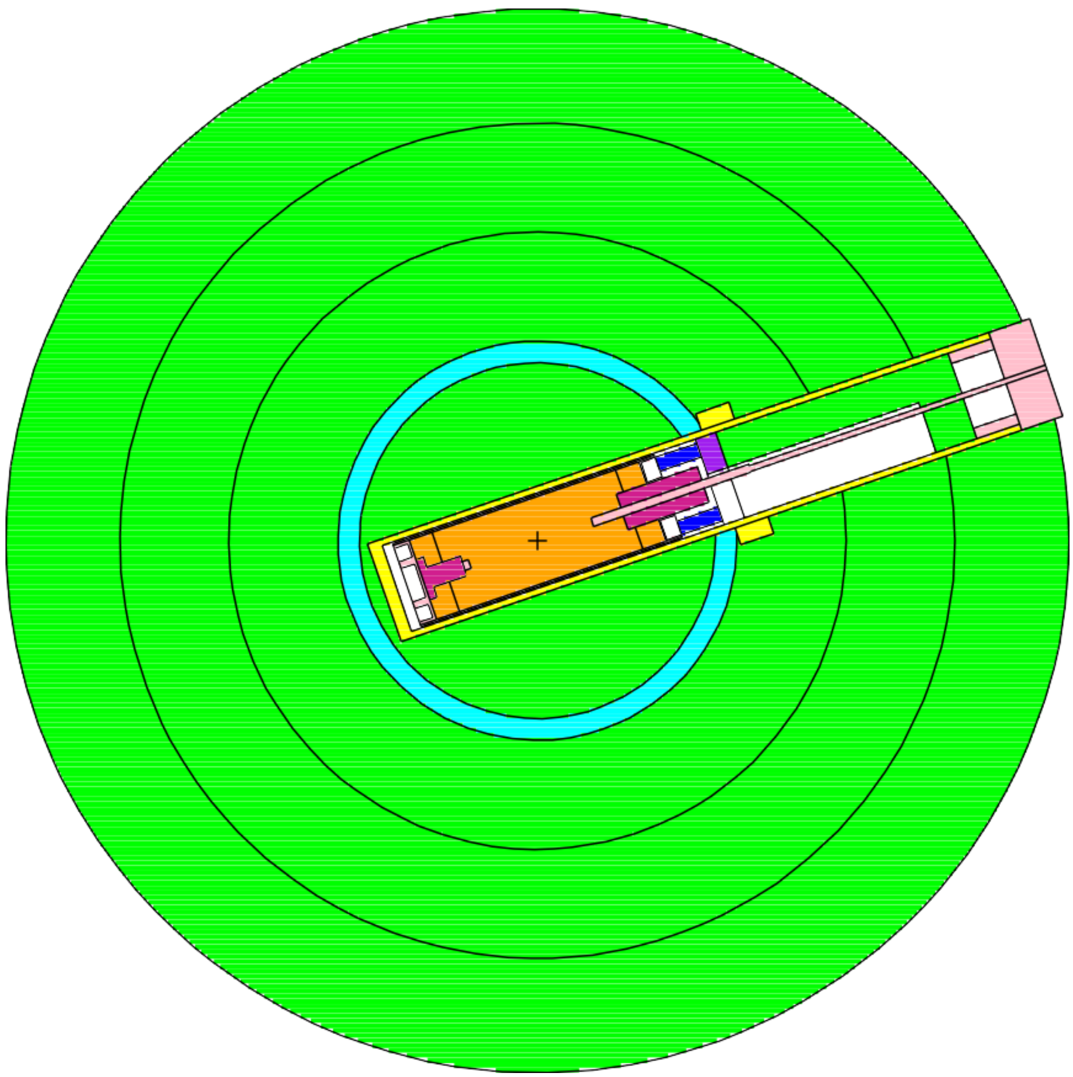
The weight of neutron dose detectors frequently exceeds 20 lbs, which can be a strain and a common cause of workplace injuries. Despite this drawback, these heavy neutron detectors have been the standard for reliable “rem-response” neutron measurements for 50 years. A few other neutron detector designs have been put forward-but none with the simplicity and ruggedness of the standard “remball”. But maybe it’s time to switch to a smaller version, shedding the weight, but keeping the good features of cost, response, and gamma rejection.

Ludlum Measurements, has developed a new remball with approximately half the weight of the older detectors. The newer detector, a Model 30-7B, been tested to ensure the same energy response and angular response as the older detectors. A picture of the new Model 30-7B is shown in Figure 1, in contrast to the older Ludlum Model 12-4. The new 30-7B does also feature a newer digital display, with more capabilities than the older detector.

Figure 1 The new and the old neutron dose “remball” detectors

These newer detectors keep the same inner He-3 proportional detector, but the outer polyethylene moderator is 7 inches outside diameter instead of the older 9 inch diameter.  Just changing the outer diameter of the moderator would reduce the response of the detector to high energy neutrons, changing the rem response.  So the inner shell moderator was changed as well to decrease the detector response to thermal neutrons.  The result is a small, lighter detector with the same overall energy response as the older detector.  Figure 2 shows a cross-sectional view of the Ludlum 30-7B detector.

*Figure 2. Cross-sectional MCNP view of the 30-7B*



The normalized energy response curve for the 30-7B is shown in Figure 3. It was generated based on a cut-off energy of 150keV – a value entirely consistent with neutron and gamma pulse height data collected previously using earlier prototypes of the 30-7B. This threshold energy in conjunction with AmBe reference field measurements with the 30-7B were used to scale the MCNP-calculated response curves. These normalized curves were then used to predict the 30-7B's response in bare Cf and $D_2O$-moderated Cf reference fields which were then compared with measurement data. Figure3 also displays, for comparison, the MCNP-calculated energy response curve for Thermo's NRD rem meter (for the 4 atm. $^3He$ tube option).

*Figure 3. Comparison of the energy response curves for the 30-7B and Thermo's 4atm. NRD rem meter*

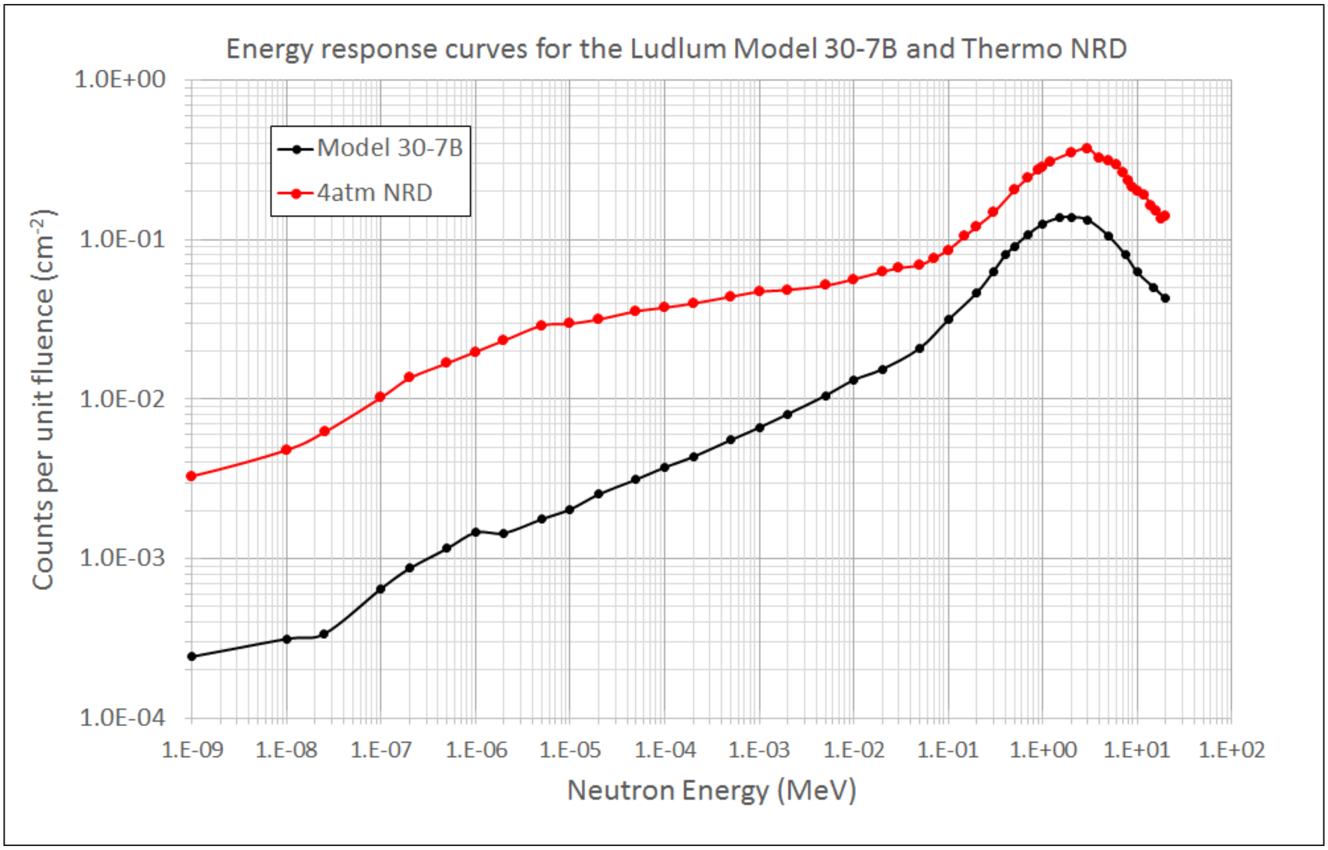


Figure 4 below plots the respective dose (H*(10)) response curves for the Model 30-7B and the 4 atm. Thermo NRD for comparison. While the two responses are similar overall, note that the ratio of the dose response (counts per mrem) at 5 keV and 2 MeV for the 30-7B has been reduced to 4.0 albeit at the expense of overall sensitivity. By comparison, the corresponding over-response ratio at 5keV and 2MeV for the NRD was previously calculated as 7.7. The newer 39-7B detector has approximately 45% of the overall sensitivity of the older detector.

*Figure 4. Comparison of the H*(10) dose response of the model 30-7B and the 4atm. NRD rem meter*

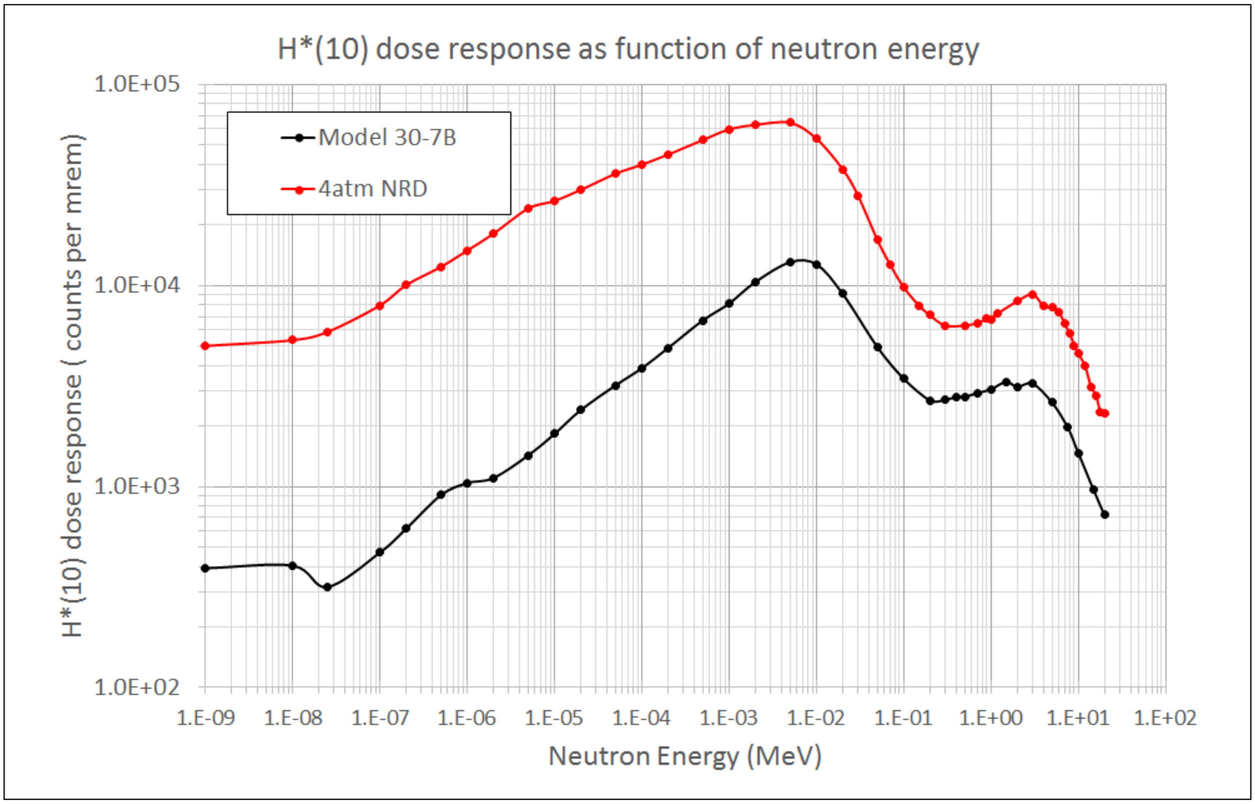



Table 1 compares the MCNP calculations with measurements made using the 30-7B in the 0 degree orientation. As the AmBe measurements were used to scale the MCNP response curves, the agreement is perfect for this source. However, the excellent agreement for the bare Cf and $D_2O$-moderated fields attests to the validity of the MCNP calculations.

*Table 1. Comparison of measured and calculated 30-7B response (at 0$^{o}$) in LANL reference fields @ 50cm*

| | Response (cpm per mrem/h) | | |
|---|---|---|---|
| Source | Measured | MCNP-calculated | % difference |
| AmBe | 45.5 | 45.5 | 0.0 |
| Bare Cf | 48.2 | 50.3 | 4.4% |
| $D_2O$-moderated Cf | 53.1 | 54.3 | 2.3% |

The Model 30-7B was also measured in three H*(10) fields generated by bare AmBe, bare Cf-252, and $D_2O$-moderated Cf-252. Table 2 shows the normalized response when the unit is calibrated to a bare AmBe source (as is used in neutron calibration at Ludlum Measurements).

Table 2 H*(10) response of the Model 30-7B in three reference fields

| New model 30-7B (S/N PR332948) | | | | | |
|---|---|---|---|---|---|
| | calibration constant: | | 2.83E+06 | count/rem | |
| source | t(s) | counts | H*(10) rate mrem/h | response mrem/h | normalized response to AmBe |
| AmBe | 240 | 5163 | 27.33 | 27.33 | 1.00 |
| Cf-252 | 120 | 15274 | 153.3 | 161.7 | 1.05 |
| Cf252+D2O | 120 | 4090 | 37.2 | 43.3 | 1.16 |

The angular response of the 30-7B was also tested using the same sources as above. The response at zero degrees was compared to the worst-case geometry, at 180 degrees. The results are shown in Table 3.

Table 3. Measured 30-7B $180^o/0^o$ ratio in LANL reference fields

| | | | | | |
|---|---|---|---|---|---|
| Bare Cf-252 | | | | | |
| | | $180^o/0^o$ | | | |
| Dist. | H*(10) | Ratio | | | |
| (cm) | (mrem/h) | | | | |
| 50 | 528 | 0.962 | | | |
| 100 | 140.2 | 0.973 | | | |
| 150 | 66.84 | 0.992 | | | |
| 200 | 40.66 | 1.048 | | | |
| | | | Average = | 0.99375 | |
| D2O Cf-252 | | | | | |
| Dist. | H*(10) | | | | |
| (cm) | (mrem/h) | | | | |
| 50 | 127.3 | 1.089 | | | |
| 100 | 34.07 | 1.119 | | | |
| 150 | 16.45 | 1.083 | | | |
| 200 | 10.15 | 1.085 | | | |
| | | | Average = | 1.094 | |
| AmBe-241 | | | | | |
| Dist. | H*(10) | | | | |
| (cm) | (mrem/h) | | | | |
| 50 | 103.8 | 0.934 | | | |
| 100 | 27.31 | 0.997 | | | |
| 150 | 12.9 | 1.011 | | | |
| 200 | 7.78 | 0.945 | | | |
| | | | Average= | 0.97175 | |
| | | | Total Average= | | 1.019833 |

Notes about the previous version, the Model 30-7:

The Model 30-7 was first introduced in 2017, and is similar to the 30-7B, sharing the same 7in.-diameter ball. The Model 30-7 has better sensitivity than the 30-7B, similar to the 9 inch remballs, and many customers were happy with the energy response. But some customers noted differences in readings between the Model 30-7 and the older Model 12-4. It was discovered that the boron content of the inner shell wasn't high enough, causing too much of an overresponse in the 5 keV region. It was also noted that angular dependence, especially at 180 degrees, was excessive, due to a lack of moderation within the detector entry shaft. The 30-7B corrects these two issues by increasing the boron content of the inner shell, and by adding a boron moderator and polyethylene spacer in the detector entry shaft. It is fairly simple (less than an hour) to replace these two parts and convert the earlier 30-7 to a 30-7B. The part number of the Ludlum conversion kit with these two parts is p/n 4014-620-01. A recalibration is required after this conversion is made.

## Summary

The new Model 30-7B has a similar energy response and produces readings similar to the accepted neutron dose detectors currently in usage, with approximately half the weight. By continuing to use the time-tested He-3 detector, users can expect immunity to high gamma fields and ruggedness of operation. The advantage of the smaller size and weight of the 30-7B is offset partially by a reduction in the sensitivity in cpm per dose rate. The previous Model 30-7 is still offered, and might be a solution if sensitivity is more important in a particular use.