# Seuratograms of Cargo Tank Pitting

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## Abstract

*Cargo tank bottom pitting is a far more critical issue for double bottom ships than for single bottom. In 1995 Hellespont Shipping undertook an unusually well-controlled set of cargo tank flat bottom thickness measurements on three 20 year old ULCC's. The results were converted to wastage distributions by tank, tank type, and longitudinal position in tank. They were also displayed as a seuratogram, a color coded scatter diagram, which revealed the overall wastage pattern. A number of surprising patterns emerged which are discussed in the paper. Overall, the results are strong support for the theory that the main cause of cargo tank pitting is oxygen differentials set up between steel that is covered with sludge and steel that is not. There is no support for microbial corrosion in these results. Implications for double bottom design and operations are discussed.*

## Keywords

Tanker; Pitting; Corrosion; Protection; Seuratogram

## 1 Method

In 1995 Hellespont Shipping undertook an unusually well-controlled set of cargo tank flat bottom thickness measurements on three 20 year old ULCC's. The goal was to decide if we should blast and coat the cargo tank flat bottoms in our fleet, and, if so, which portions of the tanks.

In each flat bottom bay, five points were ultrasonically measured in a manner that almost completely restricted the technician's ability to pick the points. This was accomplished by fabricating a stick that was as long as the bottom bay diagonal. Five pieces of chalk were fixed to to the stick at points 5%, 25%, 50%, 75%, and 95% along the stick. In each flat bottom bay, the procedure was to lay the stick along the diagonal, and a reading was taken at each chalk mark. Readings had to be taken within 5 mm of the chalk marks. The measurer was not allowed to move his instrument out of this circle. If a reading could not be obtained within this circle, the point was marked as "no reading".

All measurements were witnessed by a ship's officer. This was not a Class survey. In fact, Class was not told about these measurements. The results were for the owner's use only. The authors went on-board each of the ships to initiate the program and personally instruct the crews that this time the owner wanted accurate readings.

In one case, the Hellespont Paramount, the crew reported that they were unable to convince the measurer to follow the procedure. The measurer, an experienced thickness surveyor, simply assumed that the owner wanted "good" readings, readings that showed little wastage. One of the authors went on board found this to be the case, fired the technician, and the crew re-did the measurements themselves.

A total of about 13,000 points were measured and computerized. Table 1 shows the breakdown by ship.

## 2 Importance of Tank Type

The results were converted to wastage distributions by tank, tank type, and longitudinal position in tank. They were also displayed as a *seuratogram*, a color coded scatter diagram, which reveals the overall wastage pattern. The most complete set of measurements was done on the Hellespont Embassy. This was a 413,000 ton, five across ship built in 1976. The stringers are at the aft end of the tanks. As a ULCC, the Embassy operated mainly on very long routes, Persian Gulf to Europe and the Gulf of Mexico. We will study the Embassy, draw some conclusions, and then see how well the readings from the other ships support these findings.

Figure 1 shows the Embassy seuratogram. In this diagram less wasted areas are shown in cool colors, more wasted in hot colors. The segregated ballast tanks (4P and 4S) which were full coated with the bottom coating in excellent shape were not measured. The other tanks had bottoms which had always been uncoated. Only the flat bottom portions were measured ruling out portions of the 1, 2, 6 and 7 wings and all of the 8 wings. 5C was full coated and not measured. Since all the flat bottom plating was between 28.5 and 31 mm thick, — almost all 28.5 mm — percent wastage is a good proxy for absolute wastage. On this ship 10% wastage is about 3 mm. Figure 2 is the overall percent wastage distribution.

It is obvious that there is a strong dependence on tank type. Figures 3, 4 and 5 show the wastage distributions by tank type. On this ship, the arrival ballast tanks are 2IP, 2IS, 4IP and 4IS. These four tanks are clearly much less wasted than either the departure ballast tanks (2P, 2C, 2S, 6P, 4C, and 6S), and the cargo only tanks. Table 2 summarizes the Embassy numbers by tank type. The arrivals had a mean wastage of 2.7% less than half that of the other two types. The mean wastage in the cargo tanks was slightly less than that in the dirty ballast tanks, but significantly more variable. Table 3 summarizes the individual tank results, sorted by mean wastage.

These results came as a big surprise for two reasons:

1. The arrivals had spent much more of their time ballasted than the other two tank types. We had assumed that they would be among the worst.
2. Prior to taking the measurements, three experienced tank inspectors including two of the authors had inspected all the tanks. These inspectors agreed that the worst tanks were 1 Inners and 3 Inners. And they were very worried about the pitting in the arrivals. They thought 3C looked pretty good. One called the condition of the 3C bottom “excellent”.

In fact, the 1 Inners ranked 8th and 16th in mean wastage, and the 3 Inners ranked 17th and 18th. 3C was the worst in terms of mean wastage. The problem is the eye sees pitting; but it can’t see general wastage. 3C had a relatively low standard deviation relative to its mean.[1] The 1 and 3 Inners (and the arrivals)had relatively high standard deviations relative to their means. The ratio of standard deviation to mean is a very rough proxy for the relative importance of pitting versus general wastage.

Another big surprise is that overall the numbers were better than some unstructured readings we had taken three years earlier. The last column in Table 3 shows the average by tank from those readings. These readings were not computerized. These means are all we have. Overall the 1992 readings had a 2% higher mean wastage. And the measured wastage in the 1 and 3 Inners is among the highest tanks. In these readings, the technician who understood that the owner actually wanted the real numbers was told to take “representative” measurements. But evolution had trained the eye is to emphasize anomalies. Like the qualitative inspectors, he focused on the pitting.

Our conclusion is that qualitative inspections of tank bottoms by even the most experienced inspectors are of limited usefulness and can be badly misleading. The same thing is true of quantitative inspections unless they are carefully controlled to minimize all the biases inherent in taking these measurements.

# 3 Longitudinal Patterns

There was little athwartship variation in each tank, but as expected there was a strong longitudinal dependence. But even here there were a couple of surprises. Figure 6 shows average wastage by frame. In this diagram, Frame 0 is the aftmost frame spacing in each tank, the frame space underneath the stringers. Frame 1 is the next frame space forward, and so on. In all but nine of the tanks, this ship had five webs (six frame spaces). The central nine tanks were double length with a full swash bulkhead at Frame 6.

On average, the forward most frames in the long tanks had one third the wastage of the aftmost. This longitudinal dependence can easily be seen in the seuratogram. One result is that there is a milky way of bad wastage at the aft end of 5 wings and the 3 inners and center. This belt of 10.9% (Frame 76) and 10.3% (Frame 77) wastage is in a high longitudinal stress region. This area was missed completely in the ship’s CAPS surveys. Class took girths at Frame 71 (aft ends of 6 wings, middle of 4C and 4 Inners) anmd at Frame 83 (aft end of 4 wings ana middle of 3C and 3 Inners). The average wastage measured in these girths was 3 to 4% but of course many of thes measurements were not on the flat bottom.

The surprising feature of Figure 6 is that the worst wastage was not in the aftmost frame, but in the second last frame. We will see that this pattern also shows up in the other two ships. This is strong evidence in favor of the Shell theory of tank pitting. In 1968, Shell published a study of cargo tank pitting.[shell-1968] The work involved both laboratory experiments and field measurements in actual tanks.[2] They discovered that the steel under sludge was 50 to 300 mV more noble than areas where there was no sludge. The reason was that the sludge was allowing more oxygen to get to the steel beneath it than the liquid covering the clean areas just forward of the sludge. Oxygen is key to the cathodic reactions. Oxygen rich areas becomes cathodic relative to oxygen poor areas. Some of the potentials that Shell measured were of the same magnitude as those created by zinc anodes.

The Shell theory also explains why the arrivals were so much better than the other tanks, despite the fact that they had had much more sea water exposure than the other tanks. Crews of pre-Marpol tankers worked very hard to keep the arrivals clean. The ballast in the arrivals had to be discharged at the load port. Any oil in this ballast would generate big problems for the ship. They were far less concerned

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[1] We are not sure why 3C was the worst tank; but we suspect it was due to poor lay-up by the former owner. When we bought the ship in 1986, she had been laid up for 3 years. For some reason 3C was ballasted, even though it had no anodes.

[2] Citing a fifty year old report is very rare. But the authors know of no work of similar quality on cargo tank pitting done since the Shell study. This is a sad commentary on the demise of the major oil company marine departments, and the politicization and advertorial nature of the little public research that has been done by others relating to tankers.

about keeping the other tanks clean. The fact that these tanks had pitguards undoubtedly helped; but on the Embassy the dirty ballast tanks were also fitted with pitguards.

There is no support for the microbial theory of corrosion in our measurements. The aftmost bays were the dirtiest and the wettest, presumably the best bug breeding area. Shell also found no evidence of either bacterial attack nor sulfur activity in their work.

These measurements also indicate that most of the corrosion took place on the ballast leg. It is difficult to explain the strong longitudinal dependence otherwise. On the loaded legs, the Embassy usually operated with nil trim. If the corrosion were taking place on the loaded leg, except for the areas next to the sludge, there should not be much difference longitudinally. But on the ballast leg, the ship almost always operated with trim and the forward end of the tank was much more likely to be dry than the aft.

The relative lack of longitudinal dependence in the arrivals is another clue. Unlike the other tanks, the arrivals spent most of the ballast leg ballasted. And as the Summary by Frame in Figure **??** shows, these tanks have much less longitudinal variation than the other tanks.

Finally and perhaps most importantly, we cannot see the swash bulkheads in Figure 6. In the double length tanks, there is a full swash bulkhead at the aft side of Frame 6. Frame space 6 is covered by stringers and difficult to clean. It was clearly dirtier than the adjacent frames. If any significant amount of the the corrosion were taking place on the loaded leg, we would expect to see the same sort of oxygen differential cells working in this area as we see at the aft end. But we don't. On the ballast legs, this area is far enough forward so that in the non-ballasted tank it is normally dry, shutting down the cell.[3]

We believe that the reason there is so little corrosion on the loaded legs is oxygen availability. On the loaded legs, the only oxygen available is that which is dissolved in the thin layer of water that drops out from under the cargo. On the ballast legs, oxygen is available from highly aereated tank washing water, the ballast water itself, and the ullage space with ship motion encoraging air water mixing.

There was some longitudinal variation within each bottom bay. The little table labeled Summary by Points in the lower right corner of Figure 2 shows the aftmost point in each bay (labeled 1) averaged about 15% more wastage than the middle three points, which in turn averaged about 12% more wastage than the forward most point (labeled 5). This probably has to do with the fact that any sludge in the bay tends to end up at the aft end; but, unless the bay is at the aft end of a tank, in a spotty fashion. In any event, the variation is not nearly as strong as the dependence on overall position in the tank.

## 4 Paramount Results

Figure 7 shows the Hellespont Paramount seuratogram. The Paramount was a 388,000 ton, three across ship built in 1977. There are no stringers in 2, 4, and 7 across. The 3 and 6 across have stringers at both ends of the tanks. The 1's across have stingers on the aft bulkhead. The 5, 8 and 9 across have stringers on the forward bulkhead. Like the Embassy, the Paramount operated mainly on long routes. All the flat bottom plating is 26 mm thick, except the keelson which was 29.5. The full coated 5 wings and 9 wings were not measured, nor was 2S since the program was halted before we got around to this tank. By that time, we had enough data to realize we should blast and coat all the non-arrival flat bottoms.

Once again we see a clear dependence on tank type. On this ship, the arrival ballast tanks are 2C, 4C, 7C and 8C. These tanks are almost all green. The other tanks are mostly violet or worse. Table 4 summarizes the results by tank type. The arrivals had a mean wastage of 1.4%, the cargo only tanks, 6.6%, and the departure ballast 8.8%. In short, the pattern by tank type is similar to that of the Embassy, but even stronger. This is at least partly due to the lack of stringers in the arrivals, making those tanks easier to clean.

The overall longitudinal pattern, Figure 8. was also similar, although now the worst frame tended to be the third aftmost. The three across Paramount had much wider tanks than the five across Embassy. Therefore the stringers were much larger. The dirty areas at the aft end of the non-arrivals were more spread out.

The longitudinal dependence is not quite as clear as that for the Embassy. For one thing, the Paramount had no really long tanks. For another, there was so little wastage in the arrivals that it would have been difficult to see a pattern if it existed. The unusual stringer pattern also complicates matters a bit.

Nonetheless the overall pattern both with respect to tank type and longitudinal location in the tank is consistent with the Shell theory.

## 5 Paradise Results

Figure 9 shows the Hellespont Paradise seuratogram. The Paradise was a 315,000 ton, three across ship built in 1975. In this ships, the stringers are at the forward end of the tank. Most of the flat bottom was 24.5 mm thick, but there was some thinner plate forward and aft, in a few cases as thin as 21 mm. A major mistake in this program was analysing percentage wastage rather than absolute. We strongly

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[3] Except in the arrivals, where we do see a blip at Frame 6. The exception that supports the rule.

recommend that in the future such measurements be presented in absolute terms.

In this ship only five tanks were measured before the program was halted. All these tanke were cargo only, so we can't make any statement about tank type.

Figure 10 shows the results by frame. There is some longitudinal dependence but it is not nearly as strong as for the other two ships. All five of the aftmost frames have nearly the same numbers. We suspect that the forward stringer location is important here. There was far less tendency for the sludge to really build up at the aft in these tanks.

By themselves, the very incomplete Paradise results do not offer strong support for the Shell theory, nor can they be used as evidence against it.

# 6 Conclusions

These results support the following conclusions:

1. Visual inspections and random thickness measurements are of limited usefulness and can be badly misleading. We won't really understand cargo tank pitting until we obtain enough ***carefully controlled*** measurements.
2. The basic mechanism for cargo tank pitting is that discovered by Shell in the 1960's: the oxygen differential potentials set up between steel under clumps of sludge and nearby steel unprotected by the sludge. The Shell theory is the only hypothesis that explains why the maximum wastage was not in the dirtiest aftmost bay, but in the relatively clean areas, just forward of the aftmost bay.
3. There is no support for the bug theory of corrosion in these measurements.
4. Most of the bottom wastage occurred on the ballast legs, probably as a result of increased oxygen availability.

You must keep your tanks clean. And on the ballast legs they should be totally dry.

These results should be good news for double bottom ships which are far easier to clean and drain than single bottom. But there are a couple of caveats:

1. Segregated ballast in itself is not much help as the wastage in our cargo only tanks showed. Our cargo only tanks were practically as bad as the departure ballast tanks. The water in the cargo and from tank washing is all that is needed.
2. Newbuilding double hulls are typically delivered with only one or two COW machines in even the most enormous tanks. This results from the fact that just one or two machines satisfy the shadow diagram requirements due to the relative lack of structure within these tanks. However, the effective jet length of these machines is at most 20 meters, and in many cases the bottom is 30 or more meters away from the machine. These bottoms will not be cleaned.
3. These days inner bottoms are almost invariably made of thermo-mechanically control processed (TMCP) steel which has a much smaller grain size than the cold rolled steel used in our old ships. Corrosion is a grain boundary phenomenon and TMCP steel has far more grain boundary area than the traditional hull steels.
4. On a single bottom ship, a pit that penetrated the bottom resulted in a small spill before it was discovered. At that point, the crew had only to draw down the tank a meter or two to establish hydrostatic balance.

   On a double bottom ship, a pit that penetrates the inner bottom generates a leak into a non-inerted space. This leak can go undiscovered for some time, during which there is a chance of a major explosion or fire.

   Once the leak is discovered, there is often little a crew can do about it. Establishing hydrostatic balance requires either (a) emptying the entire tank, or (b) ballasting up the tank being leaked into. But there is rarely sufficient cargo volume to do (a), and (b) will usually over-stress the ship.

   In short, avoiding cargo tank bottom pitting is far more criticial on a double bottom ship than a single bottom.

Design implications:

1. Base COW machine arrangement on realistic jet lengths. The current shadow diagram based rules need to be changed. The corners formed by the webs and the longitudinal bulkheads are a particularly vulnerable area.
2. Put the stringers at the forward end of the tanks.
3. Use mild steel in the inner bottom, which will also reduce inter-stiffener deflection and its impact on the coating in the top of the double bottom.
4. Coat the top of the inner bottoms.
5. Put anodes right on the inner bottom.

# References

Shell (1968), "Crude Oil Cargo Tank Pitting", BSRA Technical Report no. 234, 1968.

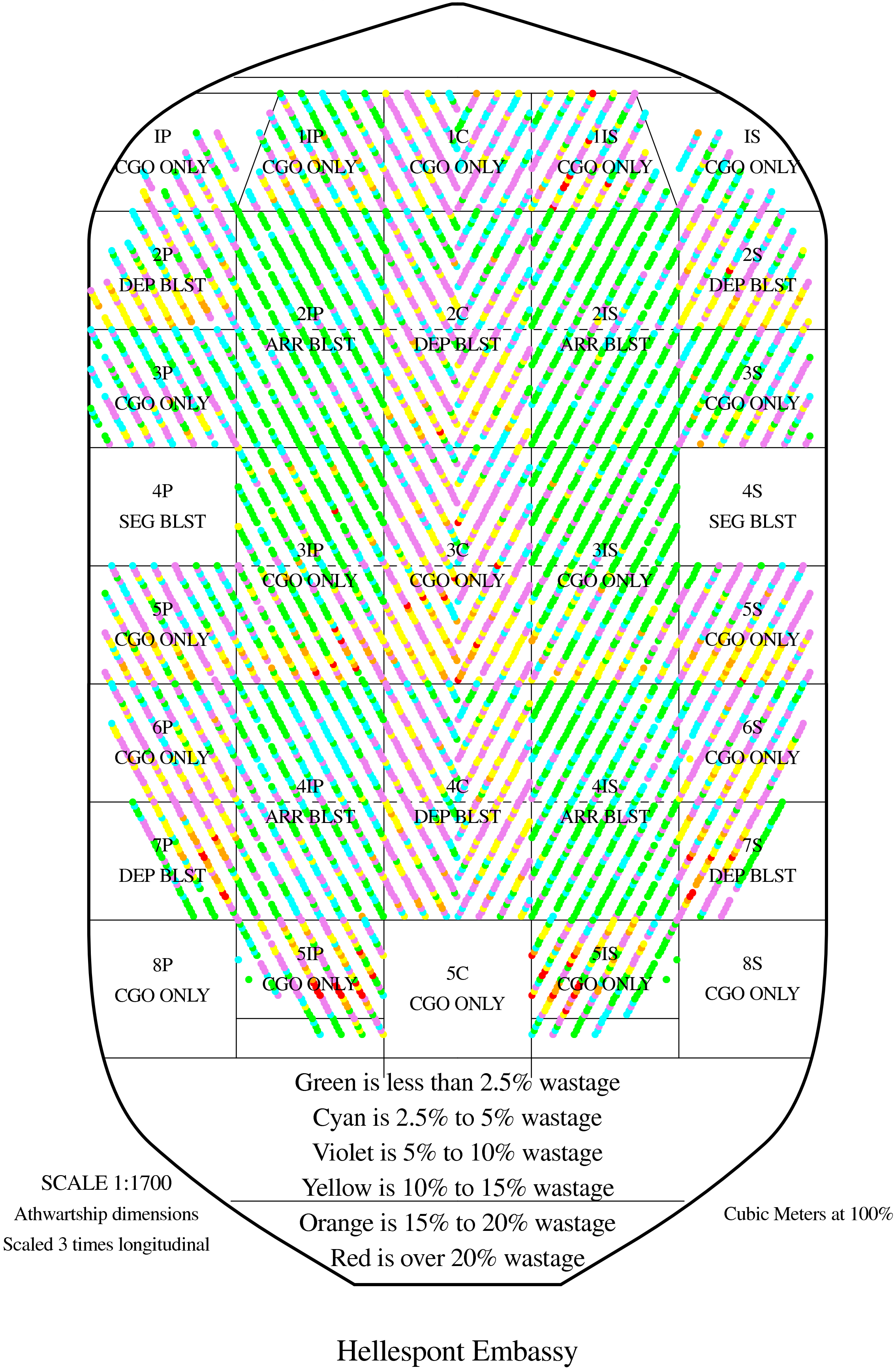


Figure 1: Hellespont Embassy Seuratogram

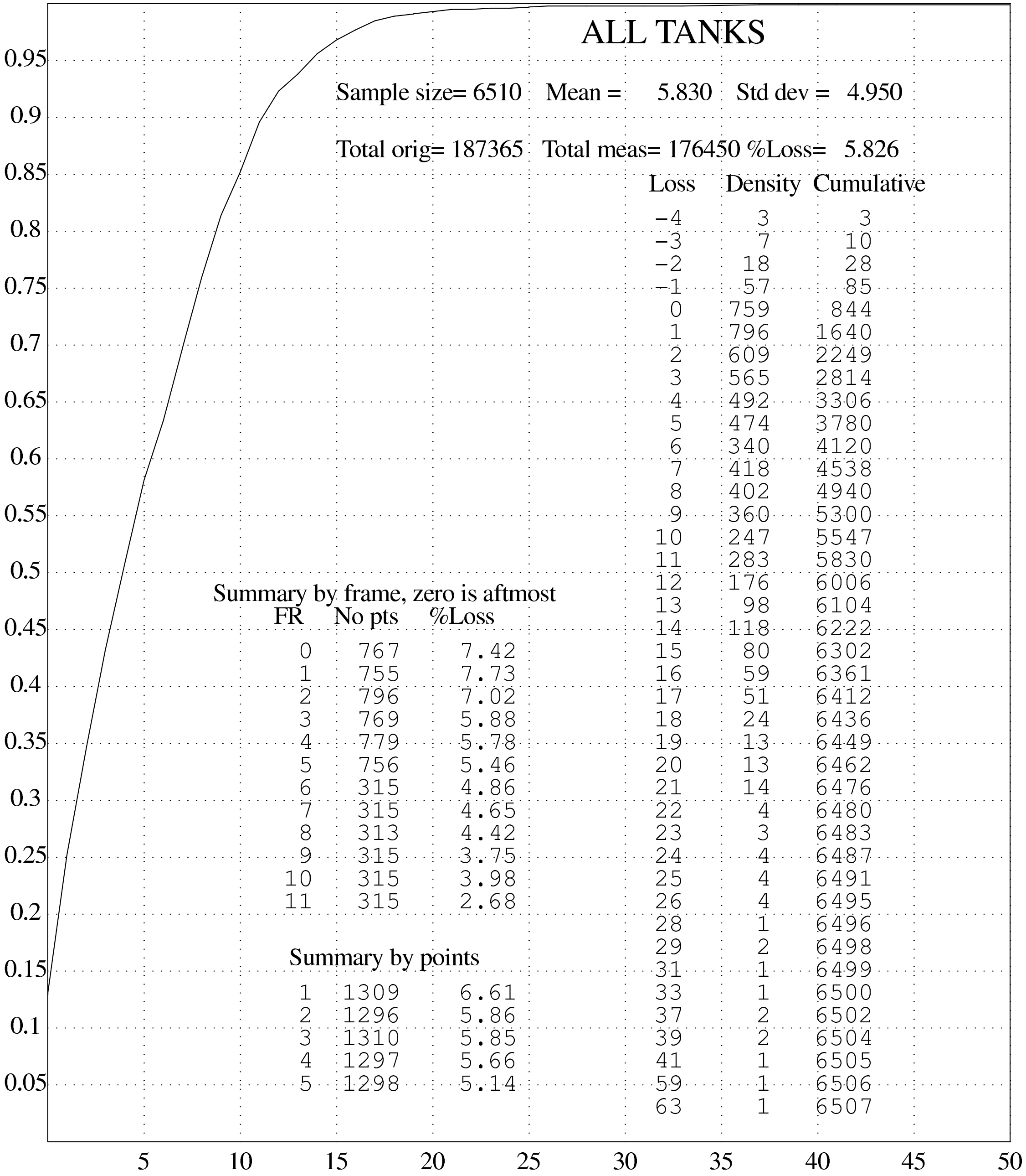


Figure 2: Hellespont Embassy Wastage Distribution, All Tanks

ALL TANKS

Sample size= 6510 Mean = 5.830 Std dev = 4.950

Total orig= 187365 Total meas= 176450 %Loss= 5.826

| Loss | Density | Cumulative |
|---|---|---|
| −4 | 3 | 3 |
| −3 | 7 | 10 |
| −2 | 18 | 28 |
| −1 | 57 | 85 |
| 0 | 759 | 844 |
| 1 | 796 | 1640 |
| 2 | 609 | 2249 |
| 3 | 565 | 2814 |
| 4 | 492 | 3306 |
| 5 | 474 | 3780 |
| 6 | 340 | 4120 |
| 7 | 418 | 4538 |
| 8 | 402 | 4940 |
| 9 | 360 | 5300 |
| 10 | 247 | 5547 |
| 11 | 283 | 5830 |
| 12 | 176 | 6006 |
| 13 | 98 | 6104 |
| 14 | 118 | 6222 |
| 15 | 80 | 6302 |
| 16 | 59 | 6361 |
| 17 | 51 | 6412 |
| 18 | 24 | 6436 |
| 19 | 13 | 6449 |
| 20 | 13 | 6462 |
| 21 | 14 | 6476 |
| 22 | 4 | 6480 |
| 23 | 3 | 6483 |
| 24 | 4 | 6487 |
| 25 | 4 | 6491 |
| 26 | 4 | 6495 |
| 28 | 1 | 6496 |
| 29 | 2 | 6498 |
| 31 | 1 | 6499 |
| 33 | 1 | 6500 |
| 37 | 2 | 6502 |
| 39 | 2 | 6504 |
| 41 | 1 | 6505 |
| 59 | 1 | 6506 |
| 63 | 1 | 6507 |

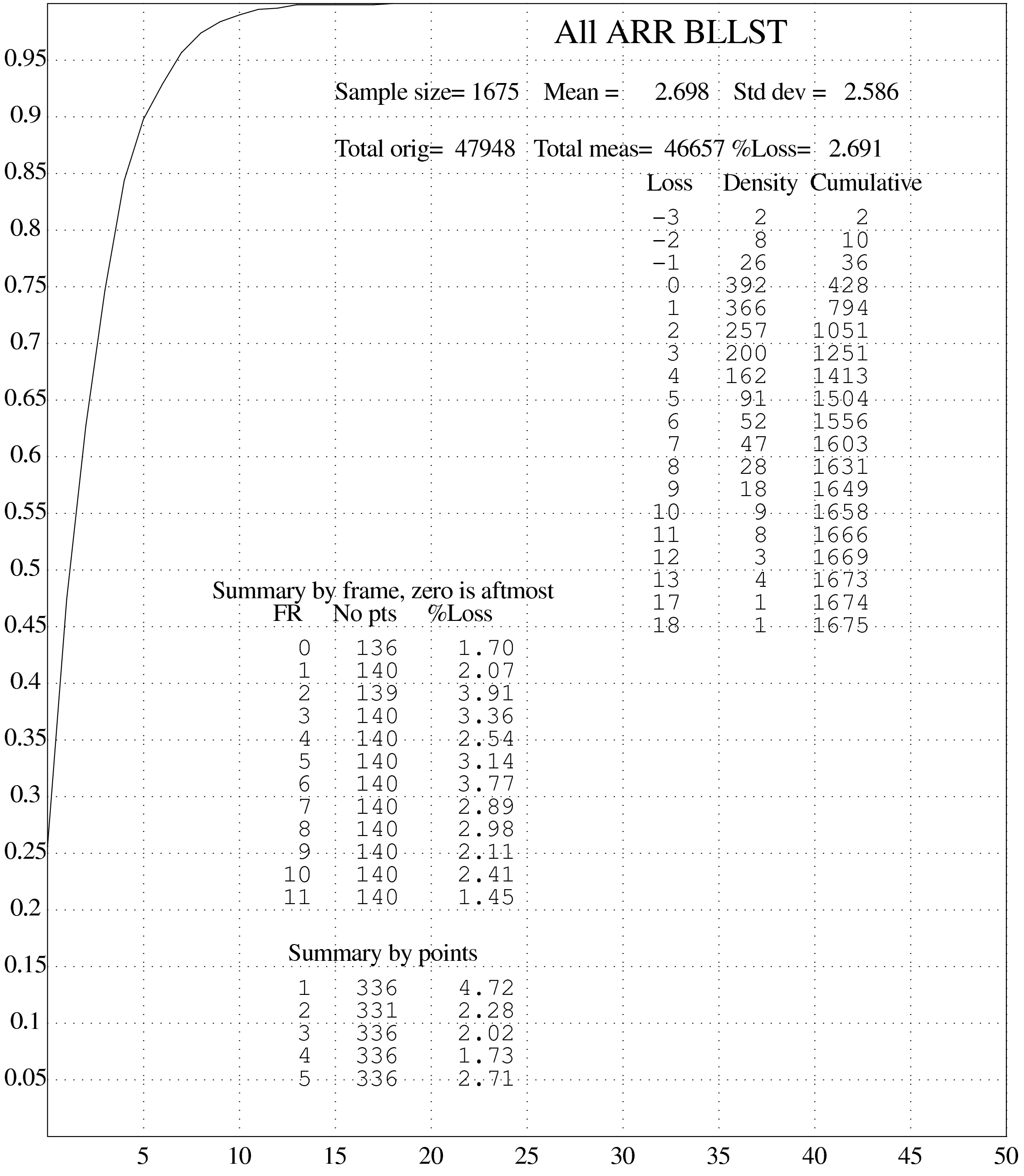
Summary by frame, zero is aftmost

| FR | No pts | %Loss |
|---|---|---|
| 0 | 767 | 7.42 |
| 1 | 755 | 7.73 |
| 2 | 796 | 7.02 |
| 3 | 769 | 5.88 |
| 4 | 779 | 5.78 |
| 5 | 756 | 5.46 |
| 6 | 315 | 4.86 |
| 7 | 315 | 4.65 |
| 8 | 313 | 4.42 |
| 9 | 315 | 3.75 |
| 10 | 315 | 3.98 |
| 11 | 315 | 2.68 |

Summary by points

| | | |
|---|---|---|
| 1 | 1309 | 6.61 |
| 2 | 1296 | 5.86 |
| 3 | 1310 | 5.85 |
| 4 | 1297 | 5.66 |
| 5 | 1298 | 5.14 |

Figure 3: Hellespont Embassy Wastage Distribution, Arrivals Only



Sample size= 1675 Mean = 2.698 Std dev = 2.586

Total orig= 47948 Total meas= 46657 %Loss= 2.691

| Loss | Density | Cumulative |
|---|---|---|
| −3 | 2 | 2 |
| −2 | 8 | 10 |
| −1 | 26 | 36 |
| 0 | 392 | 428 |
| 1 | 366 | 794 |
| 2 | 257 | 1051 |
| 3 | 200 | 1251 |
| 4 | 162 | 1413 |
| 5 | 91 | 1504 |
| 6 | 52 | 1556 |
| 7 | 47 | 1603 |
| 8 | 28 | 1631 |
| 9 | 18 | 1649 |
| 10 | 9 | 1658 |
| 11 | 8 | 1666 |
| 12 | 3 | 1669 |
| 13 | 4 | 1673 |
| 17 | 1 | 1674 |
| 18 | 1 | 1675 |

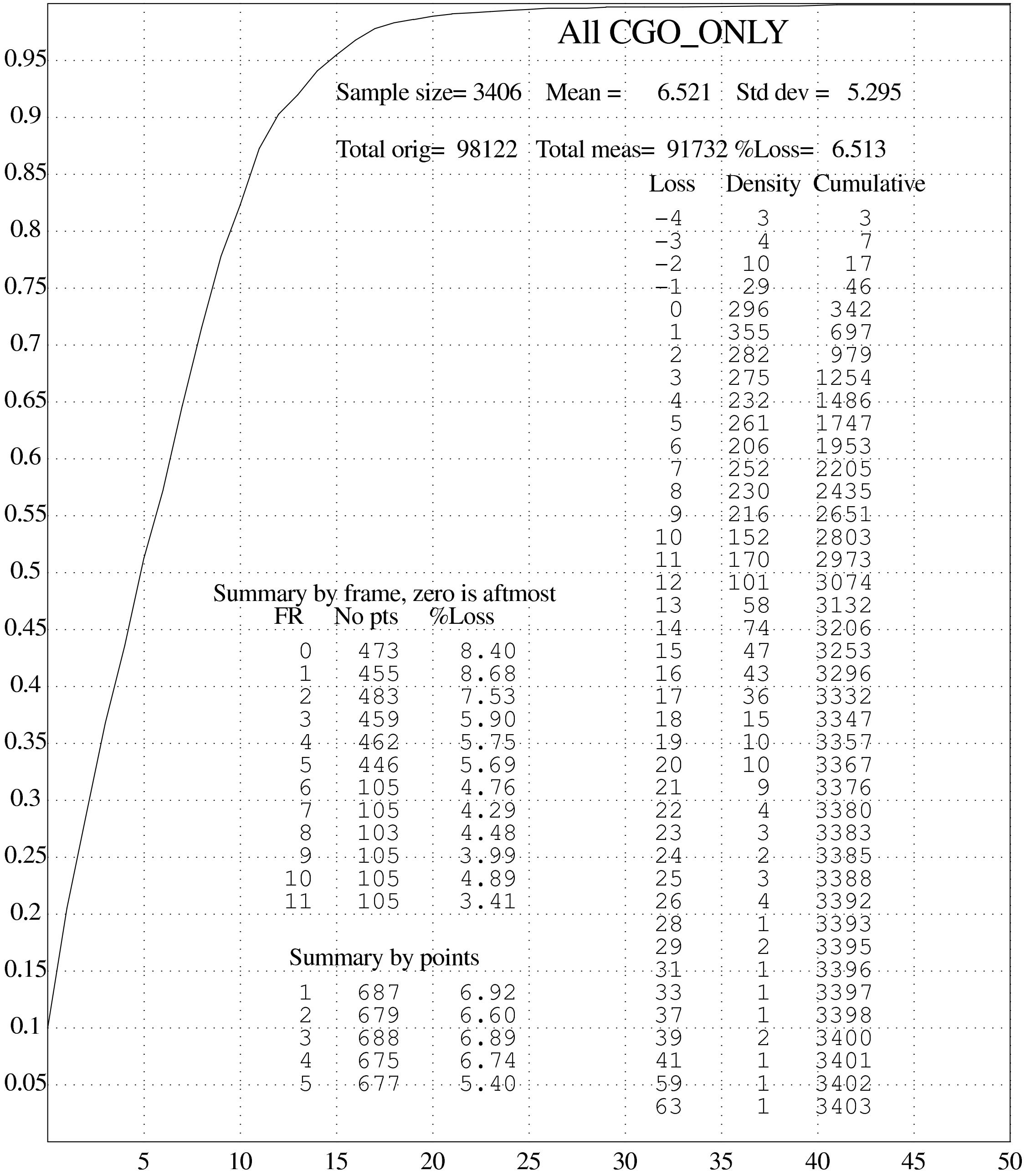
Summary by frame, zero is aftmost

| FR | No pts | %Loss |
|---|---|---|
| 0 | 136 | 1.70 |
| 1 | 140 | 2.07 |
| 2 | 139 | 3.91 |
| 3 | 140 | 3.36 |
| 4 | 140 | 2.54 |
| 5 | 140 | 3.14 |
| 6 | 140 | 3.77 |
| 7 | 140 | 2.89 |
| 8 | 140 | 2.98 |
| 9 | 140 | 2.11 |
| 10 | 140 | 2.41 |
| 11 | 140 | 1.45 |

Summary by points

| | | |
|---|---|---|
| 1 | 336 | 4.72 |
| 2 | 331 | 2.28 |
| 3 | 336 | 2.02 |
| 4 | 336 | 1.73 |
| 5 | 336 | 2.71 |

Figure 4: Hellespont Embassy Wastage Distribution, Cargo Only



Sample size= 3406 Mean = 6.521 Std dev = 5.295

Total orig= 98122 Total meas= 91732 %Loss= 6.513

| Loss | Density | Cumulative |
|---|---|---|
| −4 | 3 | 3 |
| −3 | 4 | 7 |
| −2 | 10 | 17 |
| −1 | 29 | 46 |
| 0 | 296 | 342 |
| 1 | 355 | 697 |
| 2 | 282 | 979 |
| 3 | 275 | 1254 |
| 4 | 232 | 1486 |
| 5 | 261 | 1747 |
| 6 | 206 | 1953 |
| 7 | 252 | 2205 |
| 8 | 230 | 2435 |
| 9 | 216 | 2651 |
| 10 | 152 | 2803 |
| 11 | 170 | 2973 |
| 12 | 101 | 3074 |
| 13 | 58 | 3132 |
| 14 | 74 | 3206 |
| 15 | 47 | 3253 |
| 16 | 43 | 3296 |
| 17 | 36 | 3332 |
| 18 | 15 | 3347 |
| 19 | 10 | 3357 |
| 20 | 10 | 3367 |
| 21 | 9 | 3376 |
| 22 | 4 | 3380 |
| 23 | 3 | 3383 |
| 24 | 2 | 3385 |
| 25 | 3 | 3388 |
| 26 | 4 | 3392 |
| 28 | 1 | 3393 |
| 29 | 2 | 3395 |
| 31 | 1 | 3396 |
| 33 | 1 | 3397 |
| 37 | 1 | 3398 |
| 39 | 2 | 3400 |
| 41 | 1 | 3401 |
| 59 | 1 | 3402 |
| 63 | 1 | 3403 |

Summary by frame, zero is aftmost

| FR | No pts | %Loss |
|---|---|---|
| 0 | 473 | 8.40 |
| 1 | 455 | 8.68 |
| 2 | 483 | 7.53 |
| 3 | 459 | 5.90 |
| 4 | 462 | 5.75 |
| 5 | 446 | 5.69 |
| 6 | 105 | 4.76 |
| 7 | 105 | 4.29 |
| 8 | 103 | 4.48 |
| 9 | 105 | 3.99 |
| 10 | 105 | 4.89 |
| 11 | 105 | 3.41 |

Summary by points

| | | |
|---|---|---|
| 1 | 687 | 6.92 |
| 2 | 679 | 6.60 |
| 3 | 688 | 6.89 |
| 4 | 675 | 6.74 |
| 5 | 677 | 5.40 |

Table 1: Summary of Thickness Measurements

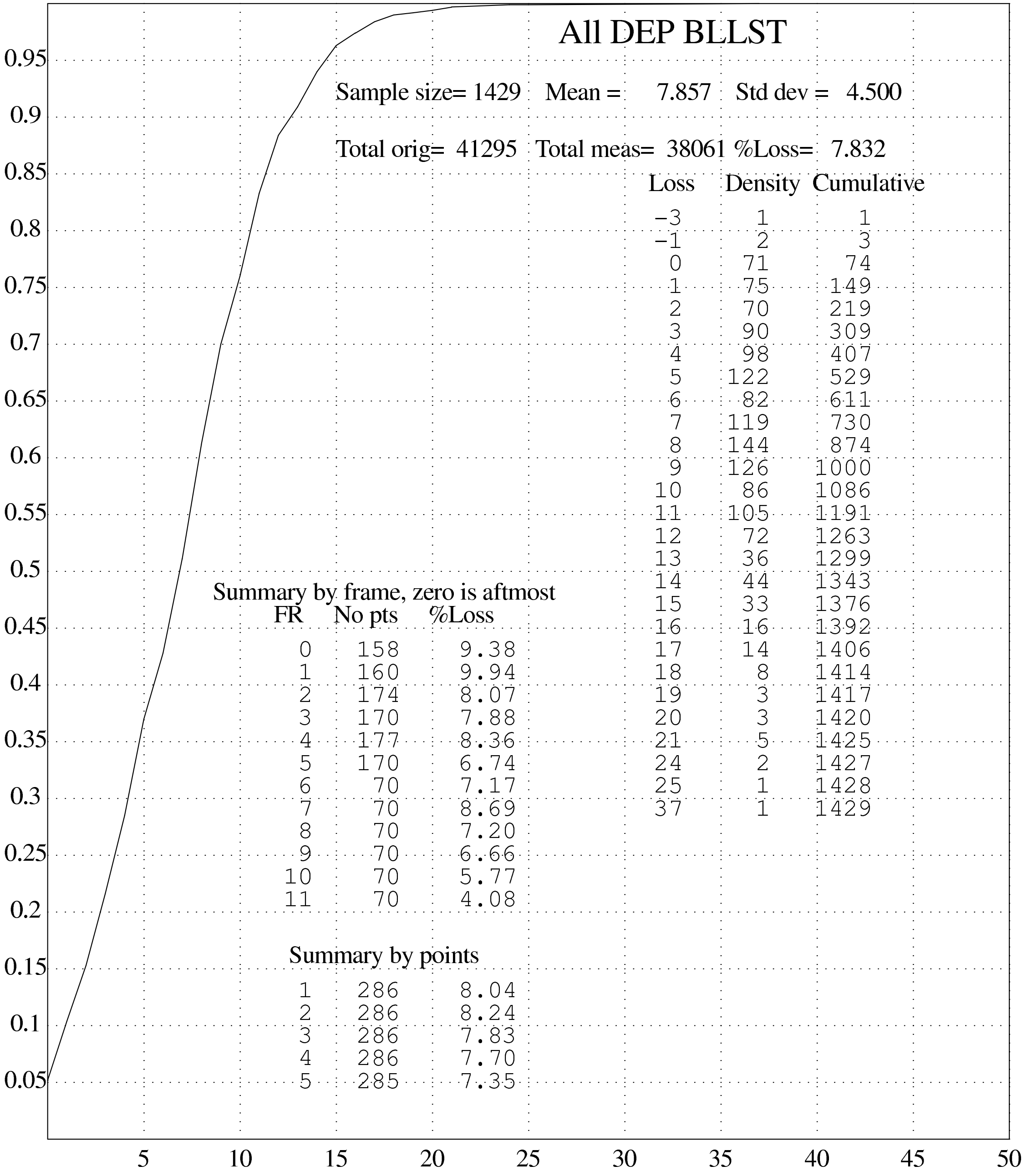
| | YOB | Points | Mean | Std.dev |
|---|---|---|---|---|
| Embassy | 1976 | 6510 | 5.8% | 5.0% |
| Paramount | 1977 | 5279 | 5.4% | 4.0% |
| Paradise | 1975 | 1278 | 9.5% | 6.0% |

(Paradise incomplete, no arrivals, no departures)

Table 2: Summary by Tank Type Embassy

| Tank Type | Sample Size | Mean | Std. Dev. | Last Frame | 2nd Last |
|---|---|---|---|---|---|
| Arrival Ballast | 1675 | 2.7 | 2.6 | 1.7 | 2.1 |
| Cargo Only | 3406 | 6.5 | 5.3 | 8.4 | 8.7 |
| Departure Ballast | 1429 | 7.9 | 4.5 | 9.4 | 9.9 |
| All tanks | 6510 | 5.8 | 5.0 | 7.4 | 7.7 |

Figure 5: Hellespont Embassy Wastage Distribution, Departures Only



All DEP BLLST

Sample size= 1429 Mean = 7.857 Std dev = 4.500

Total orig= 41295 Total meas= 38061 %Loss= 7.832

| Loss | Density | Cumulative |
|---|---|---|
| −3 | 1 | 1 |
| −1 | 2 | 3 |
| 0 | 71 | 74 |
| 1 | 75 | 149 |
| 2 | 70 | 219 |
| 3 | 90 | 309 |
| 4 | 98 | 407 |
| 5 | 122 | 529 |
| 6 | 82 | 611 |
| 7 | 119 | 730 |
| 8 | 144 | 874 |
| 9 | 126 | 1000 |
| 10 | 86 | 1086 |
| 11 | 105 | 1191 |
| 12 | 72 | 1263 |
| 13 | 36 | 1299 |
| 14 | 44 | 1343 |
| 15 | 33 | 1376 |
| 16 | 16 | 1392 |
| 17 | 14 | 1406 |
| 18 | 8 | 1414 |
| 19 | 3 | 1417 |
| 20 | 3 | 1420 |
| 21 | 5 | 1425 |
| 24 | 2 | 1427 |
| 25 | 1 | 1428 |
| 37 | 1 | 1429 |

Summary by frame, zero is aftmost

| FR | No pts | %Loss |
|---|---|---|
| 0 | 158 | 9.38 |
| 1 | 160 | 9.94 |
| 2 | 174 | 8.07 |
| 3 | 170 | 7.88 |
| 4 | 177 | 8.36 |
| 5 | 170 | 6.74 |
| 6 | 70 | 7.17 |
| 7 | 70 | 8.69 |
| 8 | 70 | 7.20 |
| 9 | 70 | 6.66 |
| 10 | 70 | 5.77 |
| 11 | 70 | 4.08 |

Summary by points

| | | |
|---|---|---|
| 1 | 286 | 8.04 |
| 2 | 286 | 8.24 |
| 3 | 286 | 7.83 |
| 4 | 286 | 7.70 |
| 5 | 285 | 7.35 |

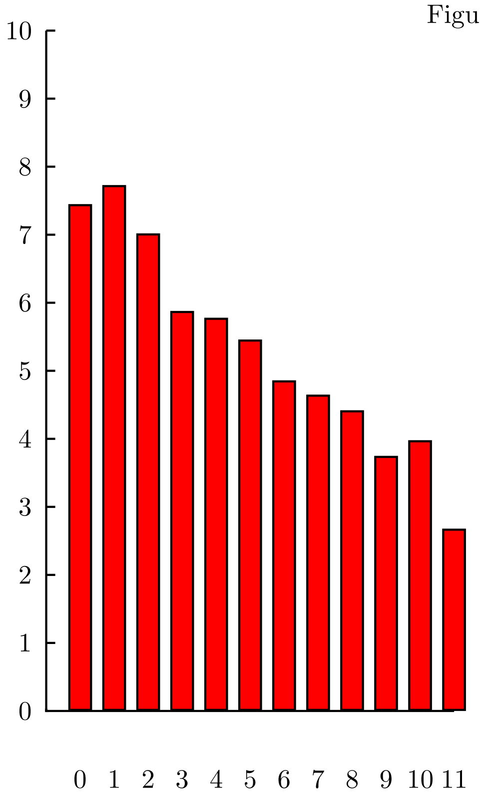
Table 3: Summary of Wastage by Tank, Embassy

| Tank | Sample Size | Sample Mean | Sample StdDev | 90% Point | Sample Mode | Last Frame | 2nd Last Frame | Surtest 92 Mean |
|---|---|---|---|---|---|---|---|---|
| 3C | 419 | 9.1 | 4.4 | 14 | 7 | 10.6 | 12.8 | 10.0 |
| 2S | 178 | 8.7 | 4.5 | 14 | 5/11 | 12.4 | 11.1 | 10.5 |
| 7P | 118 | 8.6 | 6.3 | 16 | 0/5 | 2.1 | 8.5 | 11.0 |
| 5S | 189 | 8.5 | 4.2 | 13 | 5/10 | 11.9 | 11.5 | 10.0 |
| 5IP | 170 | 8.4 | 7.1 | 17 | 12 | 3.6 | 8.0 | 5.0 |
| 2P | 179 | 8.3 | 4.5 | 13 | 4/11 | 11.9 | 12.4 | 9.5 |
| 7S | 117 | 8.0 | 6.1 | 15 | 0/5 | 7.1 | 10.1 | 9.5 |
| 1IS | 175 | 7.7 | 8.1 | 13 | 3/7 | 7.4 | 11.8 | 10.0 |
| 5IS | 175 | 7.5 | 7.0 | 16 | 0/10 | 2.8 | 7.8 | 6.5 |
| 5P | 188 | 7.5 | 4.4 | 13 | 3/9 | 10.8 | 10.2 | 9.5 |
| 6P | 170 | 7.5 | 3.6 | 11 | 5/8 | 9.7 | 9.9 | 8.0 |
| 6S | 170 | 7.1 | 3.5 | 11 | 5 | 9.6 | 10.7 | 9.0 |
| 1P | 69 | 6.1 | 3.7 | 9 | 6 | 7.4 | 5.9 | 7.0 |
| 1C | 210 | 6.7 | 3.0 | 9 | 6 | 7.0 | 7.4 | 9.0 |
| 1IP | 180 | 6.0 | 5.0 | 13 | 2/9 | 7.9 | 8.2 | 12.0 |
| 3IP | 417 | 5.2 | 5.6 | 13 | 1/10 | 11.2 | 10.8 | 10.0 |
| 3IS | 419 | 4.7 | 5.2 | 10 | 1/9 | 9.8 | 6.0 | 8.5 |
| 3P | 203 | 4.9 | 3.4 | 8 | 3 | 7.5 | 6.1 | 5.0 |
| 3S | 188 | 4.6 | 3.8 | 8 | 2 | 6.8 | 5.2 | 4.0 |
| 1S | 64 | 4.6 | 3.6 | 8 | 4 | 5.1 | 3.2 | 6.0 |
| 4IP | 419 | 3.8 | 2.8 | 7 | 2 | 2.9 | 3.1 | 3.5 |
| 4IS | 419 | 2.6 | 2.2 | 4 | 1 | 1.6 | 1.9 | 2.5 |
| 2IP | 419 | 2.3 | 2.2 | 7 | 0 | 1.2 | 2.5 | 3.5 |
| 2IS | 418 | 2.1 | 2.7 | 6 | 0 | 1.1 | 0.8 | 3.0 |
| Total | 6510 | 5.8 | 5.0 | 11 | 1 | 7.4 | 7.7 | 7.6 |

Table 4: Summary by Tank Type Paramount

| Tank Type | Sample Size | Mean | Std. Dev. | Last Frame | 2nd Last | 3rd Last |
|---|---|---|---|---|---|---|
| Arrival Ballast | 1680 | 1.4 | 1.3 | 1.5 | 1.4 | 1.5 |
| Cargo Only | 2561 | 6.6 | 3.3 | 7.7 | 7.0 | 7.5 |
| Departure Ballast | 1038 | 8.8 | 3.4 | 8.5 | 8.8 | 10.5 |
| All tanks | 5279 | 5.4 | 4.0 | 5.8 | 5.6 | 6.1 |

Figure 6: Summary by Frames, Embassy



| Frame | Points | Pct Loss |
|---:|---:|---:|
| 0 | 767 | 7.45 |
| 1 | 755 | 7.73 |
| 2 | 796 | 7.02 |
| 3 | 769 | 5.88 |
| 4 | 779 | 5.78 |
| 5 | 756 | 5.46 |
| 6 | 315 | 4.86 |
| 7 | 315 | 4.65 |
| 8 | 315 | 4.42 |
| 9 | 315 | 3.75 |
| 10 | 315 | 3.98 |
| 11 | 315 | 2.68 |

Figure 7: Hellespont Paramount Seuratogram

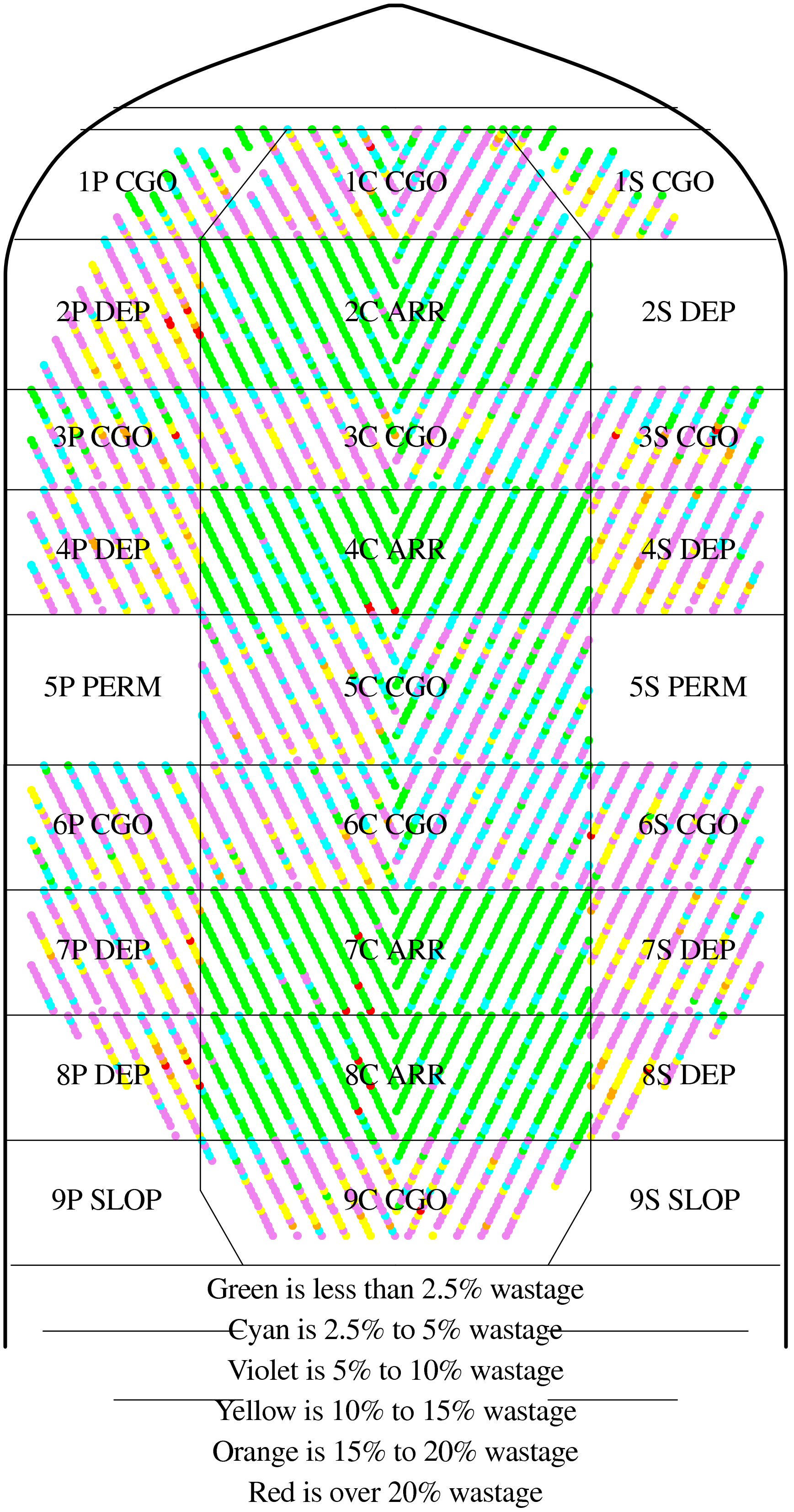
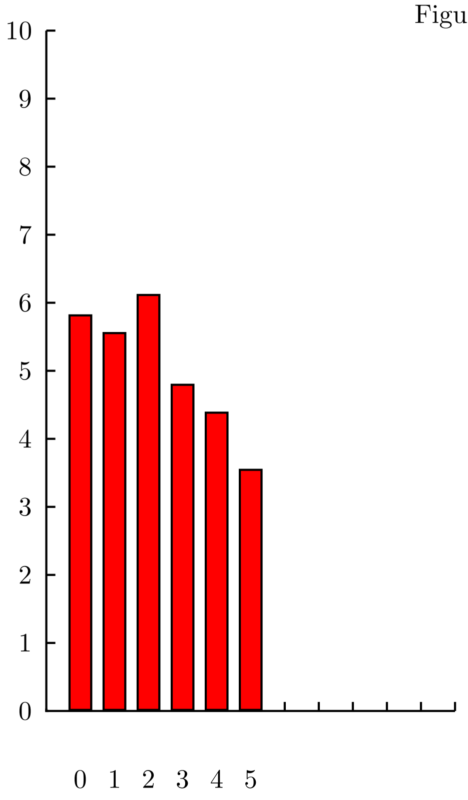
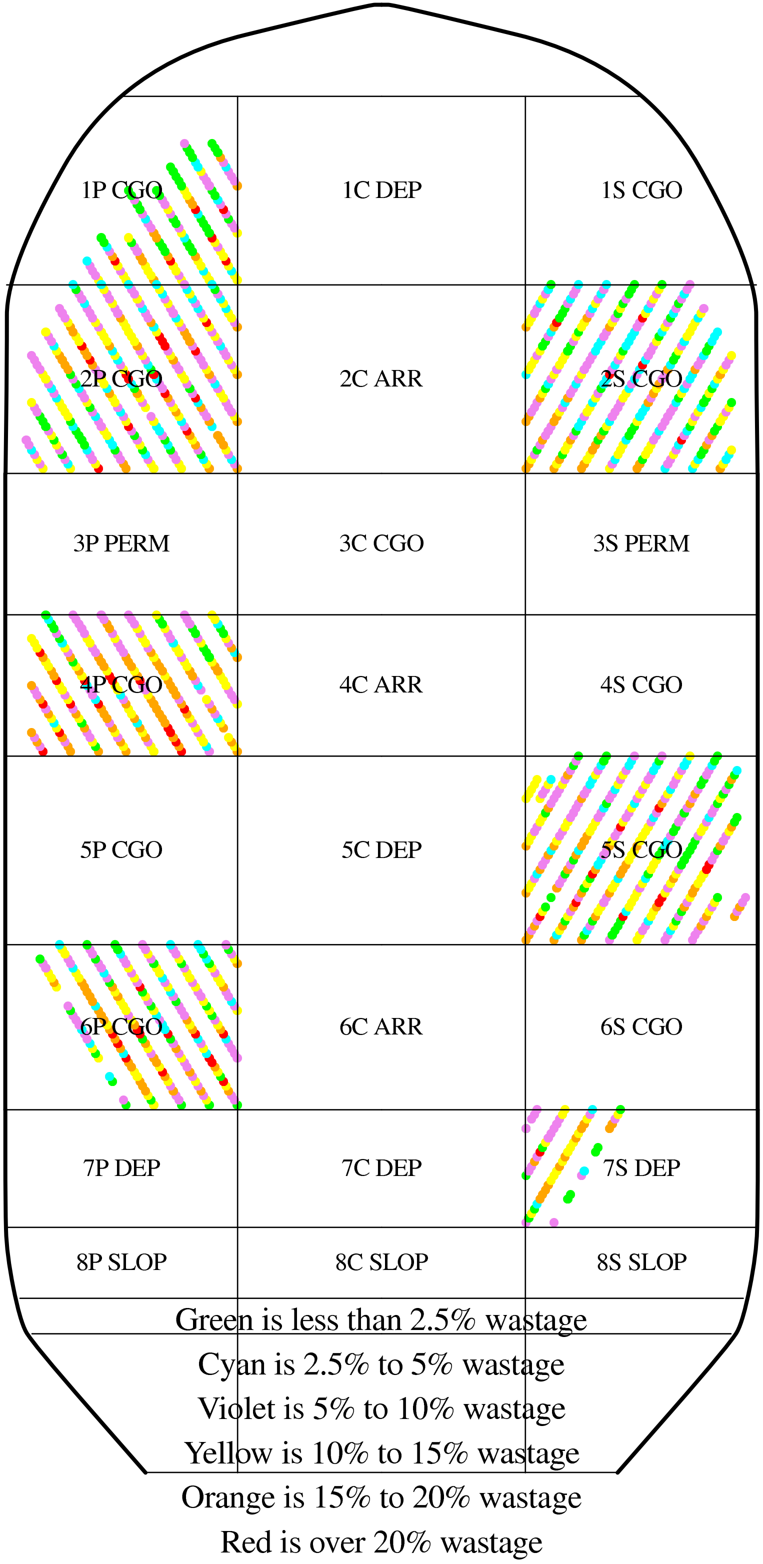


Figure 8: Summary by Frames, Paramount



| Frame | Points | Pct Loss |
|---|---|---|
| 0 | 1044 | 5.83 |
| 1 | 1060 | 5.57 |
| 2 | 1070 | 6.13 |
| 3 | 1070 | 4.81 |
| 4 | 855 | 4.46 |
| 5 | 180 | 3.56 |

Figure 9: Hellespont Paradise Seuratogram



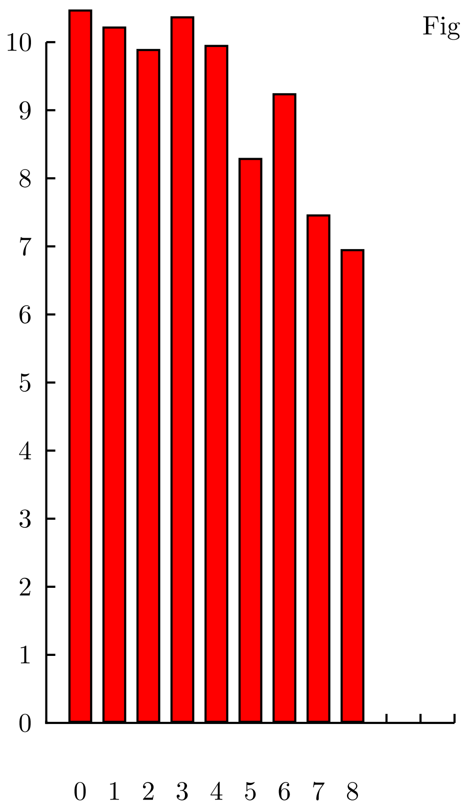


Figure 10: Summary by Frames, Paradise

| Frame | Points | Pct Loss |
|---|---|---|
| 0 | 190 | 10.48 |
| 1 | 177 | 10.23 |
| 2 | 185 | 9.90 |
| 3 | 172 | 10.38 |
| 4 | 155 | 9.96 |
| 5 | 117 | 8.30 |
| 6 | 115 | 9.25 |
| 7 | 132 | 7.47 |
| 8 | 35 | 6.96 |