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Director,
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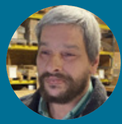
Chris Parasram
Development Engineer,
Excalibur

John Stevens is a Director of Excalibur, the 'original threaded anchor for all substrates', and has day to day responsibility for sales and operational matters including Excalibur's rail specific business.

He is a committed believer in continuous innovation and in the operational benefits smaller, more agile companies can offer the rail supply chain. John has over 25 years' experience at Director level working within the SME rail industry providing both Civil and Track related products and services, with a focus on added value solutions.

Chris Parasram is Development Engineer at Excalibur and has 42 years' experience in mechanical and precision engineering, having also run his own engineering company for 25 years.

Chris excels in finding solutions to problems from design to manufacture and especially when prototyping one-offs and small batch products. Chris has worked across many sectors including electro-glass, oil and gas, power generation, food and transport.

KNOWLEDGE 200 TRACK

EXCALIBUR SCREWBOLTS – A MODERN APPROACH TO RAIL FIXINGS

IMPROVING RAIL PRODUCTIVITY, RELIABILITY & WORKFORCE WELFARE

As an innovative British SME, Excalibur Screwbolts revolutionised the construction fixings industry and has won two Queens Awards for Enterprise Innovation. Their products have been used extensively to reliably fix numerous applications on rail infrastructure and have various Network Rail (NR), London Underground and Crossrail product approvals.

For some time now Excalibur Screwbolts have been working collaboratively with the rail industry (Network Rail and Transport for London) to provide a purpose designed fastening for baseplates on timber and composite sleepers which has been demonstrated to be easier to install and more reliable than conventional rail screw fixings.

Loose and missing rail baseplate screwspikes in timber sleepers are a commonly acknowledged problem on all rail networks, worldwide. This issue along with the significant torque (circa 2,000Nm) and large heavy machinery needed to install the traditional tapered rail AS screwspikes was the driving force behind this collaboration process.

To identify whole life cost and performance benefits a comparison assessment of the Excalibur timber sleeper bolt and AS Screwspike was commissioned by Excalibur Screwbolts with assistance from NR. The tests conducted included ergonomics, speed/ease of installation and individual product performance tests and were undertaken at Southampton University's Research Institute for Industry (RIFI), supported by NR engineers and ergonomics specialists.

Initial NR ergonomics tests confirmed Excalibur timber sleeper bolts (NR Cat No: 057/150419) were quicker and easier to install than the traditional AS screwspike. These tests also confirmed that the increased speed of installation is likely to lead to potential productivity and reliability gains, lower levels of operator fatigue and potential gains including reduced hand arm vibration syndrome (HAVS), reduced manual labour, COSHH and environmental impact.

Further laboratory testing at Southampton University's RIFI and subsequent on-track installations have all proved positive and reaffirmed these initial findings.

The question we ask is have you ever wondered why timbers split and screwspikes become loose?

This article explains in more detail the tests that were conducted at Southampton University's RIFI and explains the design differences between the two types of fixings and how they react and interface with the sleepers.

Figure 1: Configuration of strain gauge sensors.

STRAIN GAUGE TESTS ON FITTING OF AS SCREWSPIKES AND EXCALIBUR 20X163 RAIL CHAIR BOLTS

This test was performed by the use of strain gauge sensors attached to the face of the timber in an 'L' formation. (See **Figure 1**). Six sensors were used for each test, attached with three of them running across the grain and the other three running along the grain of the timber. Strain gauge 1 was closest to the drilled hole and was one of the three running across the grain. Data was recorded at a frequency of ~ 100 Hz using a Vishay Strainsmart system. All holes drilled were of the same diameter and depth; all components used for testing were new.

Figure 2 has been taken from the testing. This graph shows the strain imposed on the timber surrounding the drilled hole when the screwspikes or Excalibur bolts are inserted.

There are five of each type of bolt/spike, blue bars represent the AS screwspike and orange bars represent the Excalibur Screwbolts tested to be used as a comparison. This graph shows along the top each specimen and its identification; to the left of the graph is the strain measurement, (the higher the number, the more strain that is being imposed on the surrounding timber).

From this graph it is possible to make the observation that the traditional no. 3 AS screwspike (blue bars) has imposed a high amount of strain at nearly 1500 $\mu\varepsilon$ (micron strain, linear), and no.5 AS screwspike the least at 400 $\mu\varepsilon$. The average mean for the AS screwspikes is 1068 $\mu\varepsilon$.

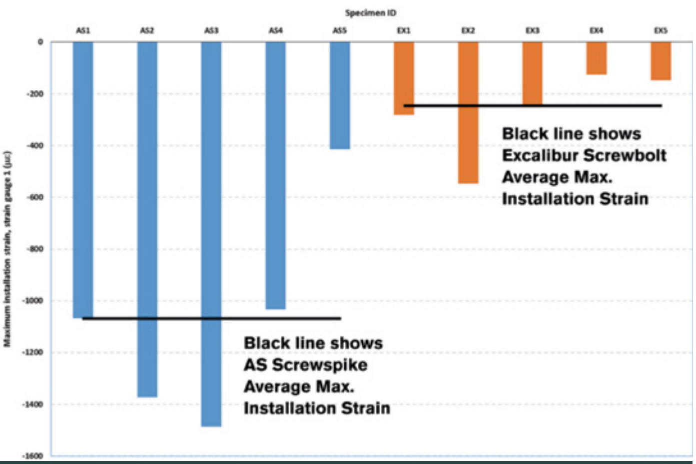

Figure 2: Strain imposed on the timber surrounding the drilled hole.

For the Excalibur chair bolt EX 2 (orange bars) shows 580 με as the highest strain, and EX 4 showing 150 με as lowest strain that is being imposed. The average mean for the Excalibur is 247 με.

The black horizontal lines on the graph shows the average mean for the AS screwspike and the average mean for the Excalibur chair bolt. This then equates to a factor of 4.32 greater strain that is being imposed by the traditional AS screwspike compared to the Excalibur chair bolt. The findings of this graph now start to give an understanding of why the AS screwspike requires such a high rotational torque to install it.

Figure 3 and **4** are plotted from the data collated from the testing; the left-hand graph is for no. 1 AS screwspike.

Figure 3 has been selected as it represents the average mean in strain for the AS screwspikes. **Figure 4** is for Excalibur chair bolt Ex 3, this graph also represents the average mean for the Excalibur chair bolt, as seen in the previous bar chart/graph.

Both **Figures 3** and **4** have at the top a scale of time measured in seconds, and to the left strain imposed measured in με (both graphs have the same scaling). When viewed in conjunction with the graph it shows strain gauges 1-3 are running across the grain, with gauge 1 being the closest to the drilled hole. The red lines on the graphs represent this. Strain gauges 4-6 are running with the grain, with gauge 4 being closest to the drilled hole. The yellow lines are representative of this.

Observation of what can be seen in these graphs.

Figure 3 is for test sample AS1, the traditional screw spike.

1. It can be seen that the fitting time for this sample is 34 seconds, this can be deduced by the point at which the coloured lines flatten out to a straighter line.
2. As this test subject is being screwed in, it is causing more and more strain to be imposed into the surrounding timber, this is evident by the lines running down the graph to the point where strain gauge 1 has recorded 1068 με, this being the average mean for the AS screwspike.
3. Consideration needs to be given to what has happened after the fitting is completed, which is shown by the strain gauge lines where they flatten out and become straighter. It will be noted that from 34 seconds to the end of the recording time (40 seconds) that the lines stay fairly static and do not head back up the graph significantly.

By seeing this it can be deduced that the strain in the surrounding timber remains, the only way these plotted strain gauge lines will move back up the graph towards zero, is when the timber splits and relieves the strain imposed in it.

Figure 4 is for test sample Ex3 the Excalibur rail chair bolt.

1. It can be seen that the fitting time for this sample is 6 seconds, this can be deduced by the point at which the coloured lines flatten out to a straighter line.
2. As this test subject is being screwed in, it can be seen that the amount of strain that is being imposed on the surrounding timber is very low. Again, this is evident by the lines running down the graph to the point where strain gauge 1 has recorded 247 με, this being the average mean for the Excalibur rail chair bolt.
3. The strain factor equates to 4.32 times less stress caused by the Excalibur rail chair screw bolt.
4. Again, consideration needs to be given to what has happened after the fitting is completed, which is shown again by the plotted strain gauge lines where they flatten out and become straighter.

It will be noted that from 6 seconds to the end of the recording time (10 seconds) that the coloured plotted lines are a constant and that any strain remaining is less than 50 με in total, as seen by how close the coloured plotted lines are to '0' at the top of the graph.

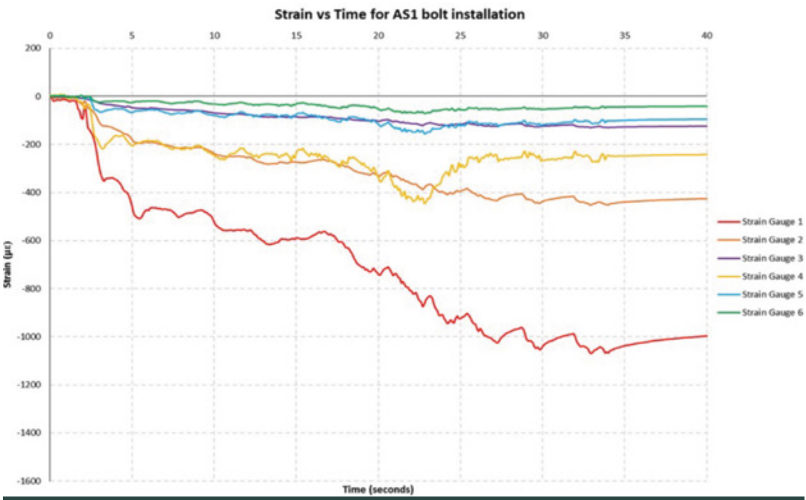

Figure 3: Strain vs. time plot for installation of AS screwspike.

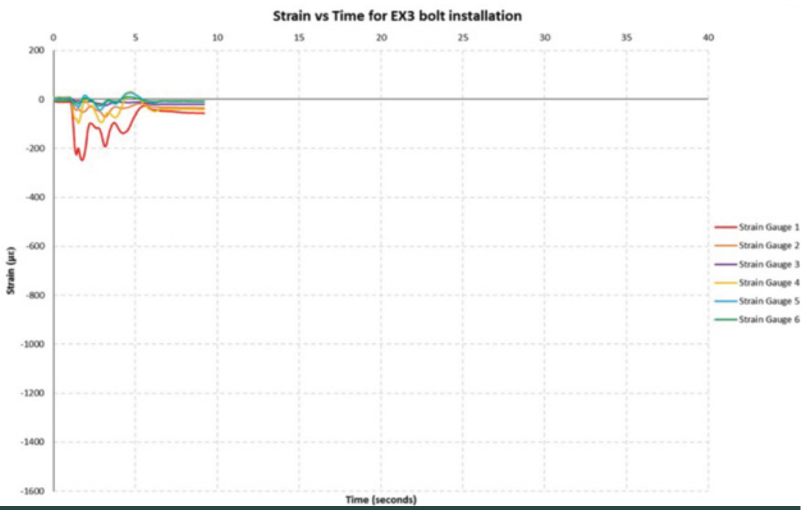

Figure 4: Strain vs. time plot for installation of Excalibur screwbolt.

From this it is possible to deduce that the chance of the timber splitting is negligible as there is next to no strain left in the surrounding timber. In both tests the AS screwspikes and the Excalibur rail chair bolts are tightened to give a clamping force, which is representative of fitting practice used by NR. The strain sensors are located 50mm from the edge of the hole, across the grain (sensor 1), and (sensor 4) is 70mm from the edge of the hole, with the grain of the timber. The other sensors are set at 25mm intervals thereafter.

Figures 5 and **6** are the test representation of axle/wheel contact loadings with the assembly of components as would be found out on track, i.e. Pan 11~ 3 bolt fixing chair/ferrules/pads/e-clips, all fitted to a 600mm long hardwood sleeper with a piece of rail 250mm long. The assembly is then loaded onto the test machine (Instron Schenck servo-hydraulic + 630KN load cell). Data collection is by the use of LVDT's (linear variable differential transducer) and recorded by using an Instron test machine controller and Wave Matrix software. The tests in each of the bar graphs below are run at a frequency of 4 Hz. Test duration is for three million cycles, to be able to recreate the dynamic type of wheel-rail loading which occurs in real-life. A vertical loading and a lateral loading of a varying force is applied, as prescribed in the BS standard.

The **Figure 5** and **6** graphs are marked to the left-hand side in microns for the movement of the spikes / bolts, and along the bottom of the graphs are marked with cycles completed and loading applied. Zero on the left-hand side of the graphs is the set point to which the screw spike and the Excalibur rail chair bolt are tightened down to for the start of the test.

Figure 5 graph shows the results for a test to the prescribed BS standard, starting with a low load for the purpose of bedding down/ running-in. At 0.6 M cycles it can be seen that there is a blue bar (AS screwspike) heading up the graph to 45 microns, at this point in the cyclic loading there is no orange bar showing (Excalibur rail chair bolt), which means it has not started to come undone. As the test progresses the lateral load force is increased from 0 to 30KN and the vertical force from 105KN to a maximum loading of 150KN. At 1.2 million cycles it can be seen that there is a small amount of movement on the Excalibur (orange bar). As the cyclic testing continues to 3.0 million cycles and ends it can be seen that the AS screwspike (blue bar) continues to rise up the chart to 107.5 microns, meaning it is unscrewing, in comparison the Excalibur rail chair bolt (orange bar) which has unscrewed slightly to 16.5 microns at the end of the test. From this it is possible to deduce a factor of 6.25 greater movement (unscrewing), of the traditional AS screwspike against the Excalibur rail chair bolt, which in turn could mean longer intervals between inspection/re-tightening. If this is the case, the sleeper longevity could also be increased by using the Excalibur rail chair bolt, because the loss of clamping force/ component stiffness with the AS screwspike increases the shear load which can then elongate the hole and require remedial repair work.

Figure 6 has been run as an over-load to try to induce failure. In this cyclic load test, there is a small bedding down/running in period of 0.9 million cycles, after this point full load is applied until the end of the test at 3.0 million cycles is reached.

In this graph it can be seen that the (orange bar) Excalibur rail chair bolt has moved up the chart to 55 microns and there is no blue bar showing, meaning no movement. At 1.2 million cycles, (now on full load), the Excalibur (orange bar) is not showing, this means that the bolt has tightened back to its '0' set point.

There is though a small (blue bar) AS screwspike which has moved up the graph to 20 microns as it starts to come undone.

At 1.8 million cycles, (still at full load), there is a small (orange bar) 5 microns uplift of the Excalibur compared to 38 microns, (blue bar) of the AS screwspike.

At 3.0 million cycles still on full load at the end of the test, the (blue bar) AS screwspike, has moved up the graph to 114 microns as it continues to come undone.

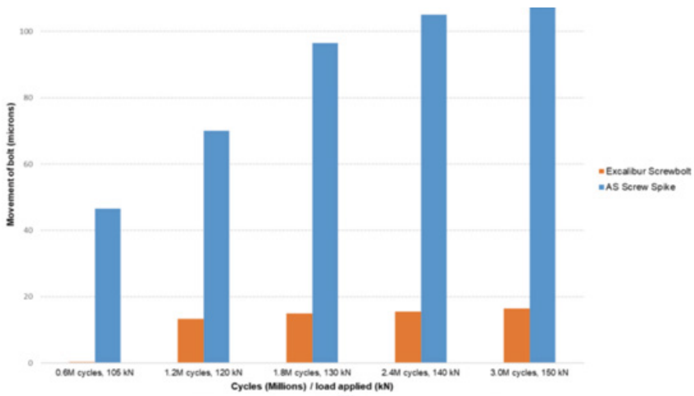

Figure 5: Comparison of movements under load cycles.

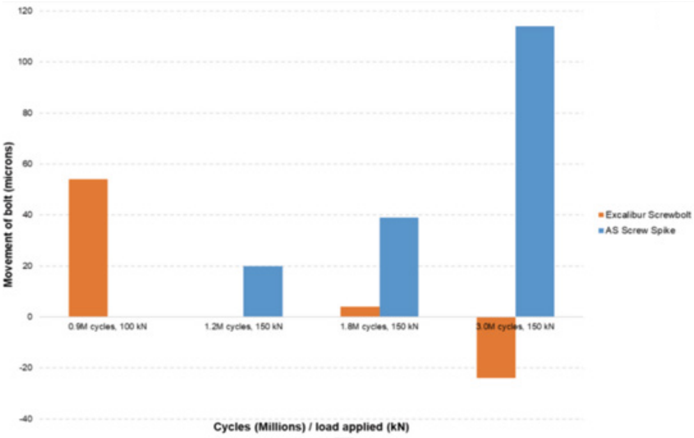

Figure 6: Comparison of movement following overload.

The Excalibur rail chair bolt (orange bar) now is plotted on the opposite side of the '0' zero line, which is the point that all test subjects were originally tightened to, this is showing a -24 micron tightening beyond the original set point for the test.

An observation from this graph, could the Excalibur rail chair bolt under harsh operating conditions be a fit and forget fixing for rail chairs?

CASE STUDY 1.

A one-year trial to improve productivity, reliability, and workforce welfare by replacing AS screws in timber sleepers for NR – Wales & Western.

Result Summary:

Reduction of each screw installation by approximately 4 seconds.

A saving of 3 hours possession time.

User-friendly operation through use of battery powered tool.

Reduced manual labour.

Reduced HAVS risk.

Reduced COSHH requirements.

Reduced environmental impact.

In an effort to find an innovative way to reduce 'boots on ballast', NR / Wales & Western undertook replacement of a large number of AS screwspikes with Excalibur bolts at its Ninian Park **(Figure 7)**, and Carmarthen stations **(Figures 8** & **9)**.

Wales & Western's James Devine is Supervisor for Works Delivery / Wales South, and was given the project to manage. In this case study, he provides insight into the work which ran from Aug 2021 to Aug 2022.

Figure 7: Ninian Park installation with Excalibur Screwbolts.

Figure 8: Carmarthen installation with Excalibur Screwbolts.

Figure 9: Carmarthen installation with Excalibur Screwbolts.

Figure 10: Chair lifting is present with AS screwspikes, and it was noted cracks appearing around holes which are failing to maintain a hold on the AS screwspikes.

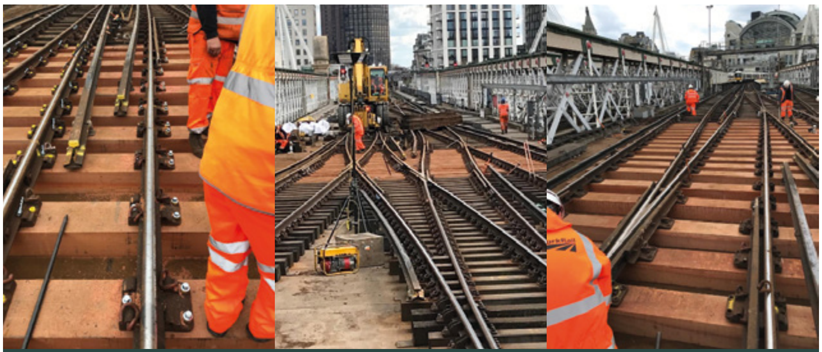

Figure 11: Charing Cross 648pts installation by Swanley Works Delivery.

"This has been an excellent trial. I was initially sceptical about using the battery technology with chair bolts, but the operatives are happy to use Excalibur sleeper bolts because of the decrease in manual effort – they go into hardwood so easily. Our operatives work 6-hour and 12-hour shifts, normally using heavy petrol-powered impact drivers, which is not ideal. We work in a high-stress environment and the less time spent on installing screws means less physical fatigue on the operatives, which has to be a good thing."

Specifications:

Ninian Park: Approximately 300 AS screwspikes were changed to Excalibur Screwbolts, utilising a battery-operated impact wrench with a high amp hour battery. The job involved renewal of 17 hardwood bearers for 9331b points throughout the switch and crossing, re-gauging of the switch and re-ballasting of the cribs. The time to screw an Excalibur bolt was an average of 7 seconds into a new timber – this compared to 11 seconds with an AS screwspike. Excalibur Screwbolts achieved an average of 80 screws per battery, with little time loss.

Carmarthen: Approximately 2000 AS screwspikes were changed to Excalibur Screwbolts on 74 points, 78 points, 72 a&b points and 71 points.

CASE STUDY 2.

NR's Swanley Works Delivery team installation at Charing Cross.

Result Summary:

No signs of star cracking around bolt holes.

No signs of baseplate lifting and Excalibur Screwbolts firmly seated.

Installation time saved.

Reduced HAVS risk.

Reduced manual labour.

Reduced COSHH and environmental impact.

Plus no lubricant needed to aid installation (additional time / money savings).

Charing Cross bridge 648pts uses extra-depth timbers, over 10 metres in length, which are stressed by high vibration with no ballast to absorb the loads. Coupled with water ingress they had degraded, so NR's Swanley Works Delivery team were tasked with installing new chair bolts at the Charing Cross location. This site was particularly noted for failures brought on by the timbers frequently expanding and contracting over and above standard tolerances **(Figure 10)**.

Commencing in April 2022 approximately 500 Excalibur Screwbolts were supplied for installation in 18 no. 10m+ timbers and 3 no. 2.6m timbers **(Figure 11)**. The timbers were drilled out using 19mm drill bits using sleeper drills and Excalibur Screwbolts driven in with 30mm hex head attachments using Bance petrol powered impact drivers. No lubricants were used to aid the installation. Typically, sites using hardwood sleepers and AS screwspikes have had to lubricate the screwspikes to stop them overheating from the force of the screw being driven in which causes heavy friction and slows down the installation, and can cause splits in the timbers (see **Figure 12**). In June 2023 Swanley Works Delivery reported on the site, with the following results, despite evidence of water ingress and hot weather effects on the timbers:

- No signs of star cracking around bolt holes
- No signs of baseplate lifting
- Excalibur Screwbolts are firmly seated
- Installation time saved
- Reduced HAVS risk
- Reduced Manual Labour

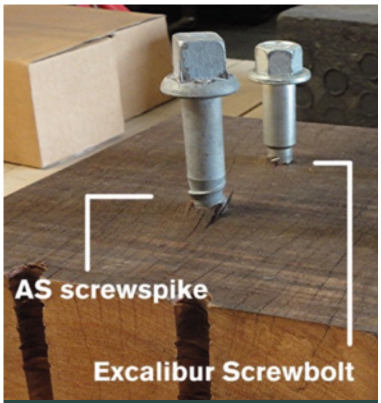

Figure 12: Increased fitting damage caused by traditional rail AS screw spikes to timber sleepers, (similar damage would be caused in plastic sleepers).

Figure 13: Excalibur Screwbolts firmly seated.

CONCLUSION

The results of the RIFI tests and track installations confirm that Excalibur Sleeper Bolts require substantially less torque to install than traditional rail screw spikes and are therefore quicker and easier to fix.

Lower whole life cost benefits and efficiency gains can be achieved along with reduced sleeper damage leading to extended asset life and reduced maintenance costs.

The vibration resistant Excalibur twin helix thread design imposes minimal stress to the timber sleeper and does not require the use of heavy petrol-powered impact wrenches for installation.

In addition, the report noted; Using 19mm drill bits as per standard for timbers, the Excalibur Screwbolts could be initially inserted into the drilled holes very easily. When driven into the timber rather than applying outward pressure at the top of the hole to hold the baseplate like standard AS screwspikes the Excalibur Sleeper Bolts cut their own thread into the timber. As a result, the Excalibur bolts work with the impact wrench to drive bolts into the hole, making installation quicker on each bolt and resulting in time savings that allows an increase in the volume of job scope within a given time. Unlike traditional rail screwspikes there was no lubricant required to aid driving the Excalibur bolts in, and reductions in manual handling and HAVS risk, site tidiness and time saved were recorded. The report concluded that Excalibur Screwbolts would aid in a quicker transition to battery powered tools given how easily they can be inserted, which would have an even greater impact on workforce welfare, HAVS risk, COSHH and environmental impact **(Figure 13)**.

On track installations of Excalibur Sleeper Bolts support the use of battery powered equipment in real life application.

Health & Safety benefits include reduced HAVS risk, Manual Handling, COSHH & Operator Fatigue.

Excalibur Sleeper Bolt key benefits are:

1. Quick & Easy to Install = Time savings, improved productivity & workforce welfare benefits including reduced HAVS risk, manual handling, COSHH & operator fatigue.
2. Reduced fixing installation damage = Improved safety & reliability.
3. Twin helix thread profile imposes minimal stress to sleeper on installation = Extended sleeper life & repair cost savings.

Further reading on technical data is available on request from Excalibur.

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