Radio and the early Direct Current (DC) Mains in South Australia

by Lloyd Butler VK5BR

The article discusses circuit systems used to operate broadcast Receivers and amateur radio gear on DC mains. It specifically refers to the town of Murray Bridge before 1953 when it was powered by 460 Volt DC. It also describes a little of the history when, in 1946, the Adelaide Electric Supply (on AC) and other regional power systems in the State, were taken over by the Government. The Electricity Trust of South Australia (ETSA) was formed and proceeded to spread ETSA AC mains right through the State .

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Introduction

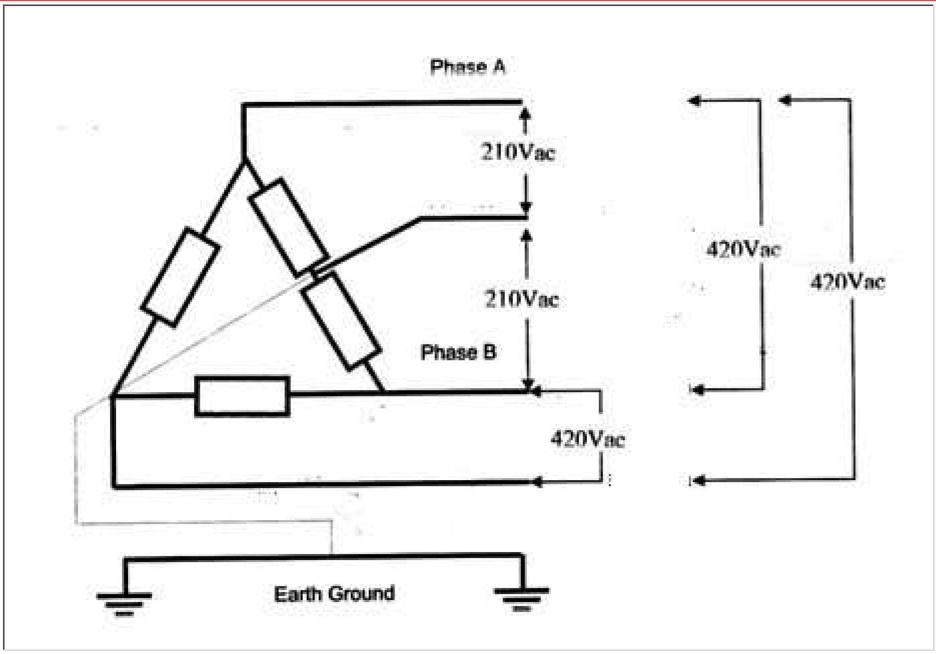
DC power mains operated in many towns in South Australia around the 1940 era. I will start with a little bit of history on how power systems developed in this State from that era and then proceed with some specific detail on how we changed the circuits to convert AC operated broadcast receivers to operate on the DC mains. I will discuss further the problems we had to solve as radio amateurs to get our ransmitters working on those mains.

Some History of mains Power Distribution in South Australia

To introduce this subject, I will describe a little about the power distributed around South Australia in the 1940/1950 era and how it all developed in later years . Prior to 1946, AC power was delivered around Adelaide and its suburbs by private company, the Adelaide Electric Supply Company (AESC). Distribution to many customers was via a split delta system. I am not sure how universal this system was throughout the supply distribution, but it was certainly the system in the Adelaide Suburb in which I had lived.

In this system, the delta secondary of one phase of the three phase distribution transformer was centre tapped, and about 210 volts was developed from the tap to one outer connection of the delta. This was fed to the consumer. I assume the total load was distributed from around all three phases, in the same way, using both halves of each delta connected secondary to essentially balance the load.

The Adelaide power was sourced from two black coal fired stations (labeled A and B) on the Port Adelaide River at Osborne. Osborne A station was originally opened in 1923. Osborne B started in 1947, and expanded to be fully complete by 1965, phasing out Osborne A. The black coal was sourced from New South Wales but later Leigh Creek brown coal was used.



The Split Deta System of Distribution
used by the Adelaide Electric Company

In regional South Australia, the towns generally had their own power distribution from their own generating stations. However towns such as Murray Bridge and Mt. Gambier distributed Direct Current (DC). To quote Murray Bridge, it distributed 460 volts of DC via a three wire system, two outer poles with a neutral at the electrical centre. The outer poles were alternatively connected to successive houses to balance the load. Each house received 230 volts but the connection alternated between a positive outer pole and a negative outer pole. The negative outer pole, referred to the neutral at earth potential, was a bit of a challenge for connecting electron tube circuitry. We will discuss this later. The 460 volt distribution was sourced from the power station on Mary Terrace using diesel powered generators.

The power station at Murray Bridge commenced in 1919 and was originally privately owned, but in late 1944, the station and the town distribution was taken over by the Corporation of Murray Bridge. The power system for Murray Bridge was well engineered but towns with a smaller population base operated with some lesser standards. For example, the power system for Ceduna was managed by the local garage and the generator was located at the rear of the garage.

The problem with the DC power was that it was distributed via heavy copper cables all the way to distant loads at the nominal load voltage. It was often difficult to maintain voltage at distant locations due to loss in the cables. The advantage of converting to alternating current was the use of transformers to step up the voltage for long distribution links to reduce the cable I^2R loss.

Over the years the Leigh Creek coalfield had developed and the State Government wanted to make use of its brown coal to generate electricity. AESC had a monopoly on the generation of electricity in Adelaide and refused to modify their power stations to take the brown coal. Tom Playford was the State Premier at the time and he managed to get through Parliament a Bill to nationalise the State electricity supplies. So in 1946, Adelaide Electric was taken over by the Government and became the Electricity Trust of South Australia (ETSA). But it didn't stop there. ETSA spread its high voltage lines throughout the State and towns were supplied with Alternating Current (AC). Power was also fed to farms and other remote locations which had previously only had wind powered, or small generator sets, floated across low voltage batteries.

ETSA expansion included building of new power stations. Playford Power Station, in the vicinity of Port Augusta opened in 1963. Torrens Island Station A was completed in 1967 and Torrens Island Station B in 1976. The Northern Power Station near Port Augusta was commissioned in 1985. The Port Augusta stations use Leigh Creek brown coal. The Torrens Island stations now use natural gas which is piped from Cooper Pedy Basin and which commenced in 1969. The Playford station, considered the most carbon polluting station in Australia, was closed down around 2012. This was partly due to the pressure on carbon emission and the carbon tax and partly giving regard to the limited life of the Leigh Creek coal mine. The Osborne B station was de-commissioned in 1989-90.

In February 1953, the town of Murray Bridge started to receive AC power from ETSA. In February 1954, the DC power station at Murray Bridge closed down.

Contrary to the Parliament's previous decision which nationalised the State's power system in 1946, in 1998 the Parliament voted to sell the ETSA power network to private interests. (I think Sir Tom Playford, the father of establishing the State owned ETSA, would have turned over in his grave.) The power stations were taken over by different companies. ETSA Utilities, then as a private company, took over the ETSA name and became responsible for the power distribution. Numerous different retail companies now sell the power to the consumers instead of ETSA. According to an article by the State Minister of Energy (The Advertiser 29-9-13), there are currently 16 retailers who buy power at a wholesale rate and sell it retail to the consumers. In September 2012, ETSA Utilities changed its name to SA Power Networks and is now owned by two different groups, one which is based in Hong Kong.

Whatever the ownership, the State power system has moved on. It now has a number of power interconnections with the Eastern States power grids. It leads Australia in the installation of wind power systems.

In 2012,wind generators were supplying 26% of the State's electricity. In wild weather, the wind power system can supply more than half the State's electricity load. Indeed, on one windy night in September 2013, it supplied three quarters of the State's night load.

It has been estimated that Leigh Creek coal will run out in year 2017. The coal mine, and the two power stations which have used the brown coal, are now owned by Alinta Energy company. At the present time, Playford station B remains moth-balled and the Northern station runs for six months of the year.

A plan is being considered to replace the coal fired stations with a solar thermal plant at Port Augusta, when the coal runs out. The thermal plant would include liquid salt heat storage so that the plant could supply electricity when there was no sun (an advantage over most photovoltaic solar systems). To extend the time available to complete this proposal, Alinta is also examining technological advances which could blend in deposits of lower quality coal, previously considered not economical to use. It is thought that this could extend the life of the Northern Power station to year 2030.

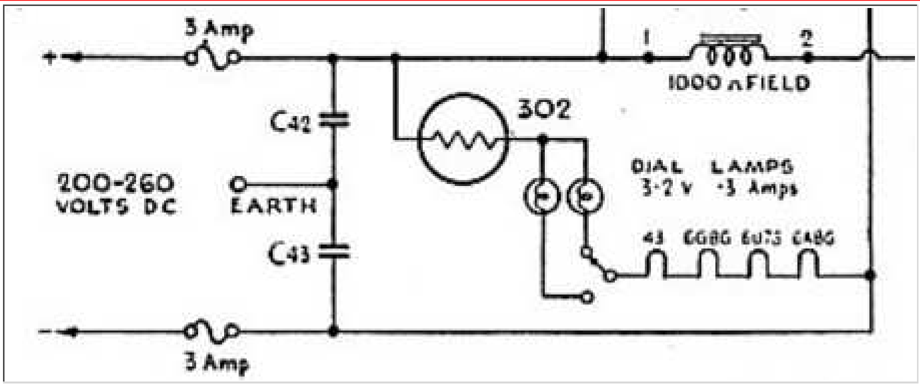
But let's return to the 1940-50 era.

Broadcast Radio Receivers and the DC

Around 1941, I worked for a while for the owner of a radio and electrical business located in the main business street of Murray Bridge. My main job was finding faults and repairing broadcast receivers and any other electrical or electronic gear which was brought into the shop. But I also carried out a lot of conversions to DC powering on receivers originally designed for AC.

A lot of the conversions were on the AC receivers brought in by customers who had moved from the City where they had AC power. But I also did the conversions on various new models of the AWA Radiola. My boss (Alan) was the agent for the AWA sets. Whilst AWA manufactured a few odd models for DC or AC/DC mains, Alan was able to display a better range of models by ordering in AC receivers and converting them to DC.

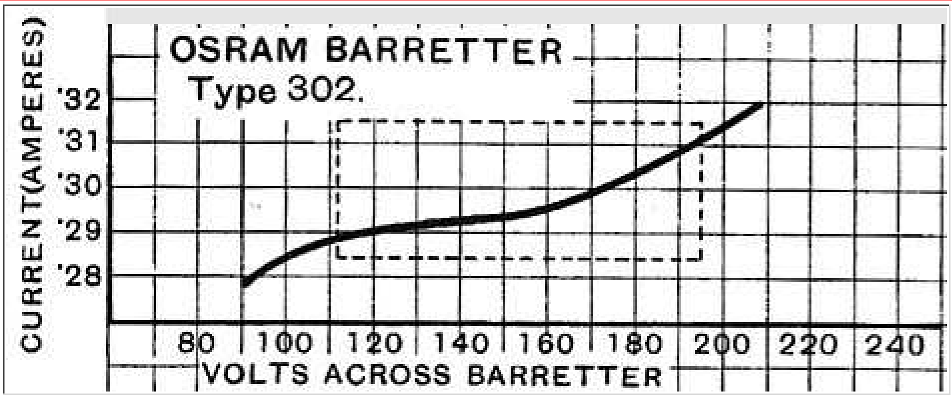
So I am about to describe what had to be done to make those AC receivers work on the DC mains. The first operation was to series connect the valve heaters which had previously been connected in parallel. Most of the sets that we worked on had heaters of 6.3 volts running at 0.3 amp, except for the audio power amplifier which ran at higher current. For example, the power pentodes type 42 and 6F6 operated at 0.7 amp, and beam power tetrode 6V6 at 0.45 amp. These were replaced with 25 volt 0.3 amp valves with similar electrical characteristics and identical plug in bases. For these three valve types, the replacements were the 43, the 25A6, and the 25L6 respectively.



The Series Heater Circuit of an AWA Radiola
designed for use on DC Mains

(The Switch? - This selects between the dial lamp illuminating the Broadcast Band display and the dial lamp illuminating the Short Wave band display)

In most cases the series heater chain was connected to the 230V DC via a 302 barrettor. The barretter was essentially a fine iron wire resistance element encased in a glass envelope evacuated, or filled with inert gas, similar to an incandescent lamp. The element ran at a temperature sufficient to show a slight red glow at the nominal voltage developed across it. At the running temperature, the element resistance was highly sensitive to change with considerable increase in resistance for a small increase in current. Hence the barretter worked as a regulator to maintain a fairly constant current flow at 0.3 amp, independent of voltage variation developed across it.

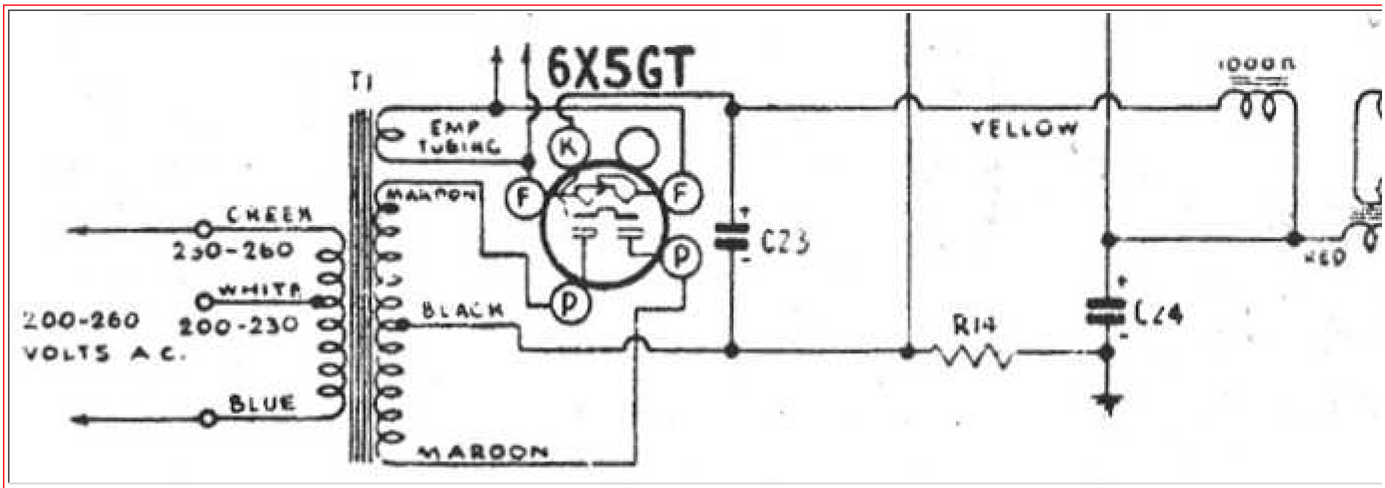


The 302 Barretter Current v/s Voltage Curve
(Note that for a voltage range of110V to 195V,
the current change is only 20 mA.)

Sometimes we had to convert a receiver with the Philips/Mullard series of valves with 6.3 volt 0.2 amp heaters. In this case we used the type C1, 0.2 amp barretter and had to replace the power valve, which ran higher current, with one which was 0.2 Amp at a higher voltage.

Sometimes the heater currents were somewhat different and we constructed resistors which were wired in series with the heaters. The resistors had to dissipate around 50 watts and were wound with nichrome wire on asbestos tubing. (The tubing had to be cut to length and drilled to take the wire ends. I shudder now to think about the fact that I could have breathed in those asbestos fibres).

In the era I am talking about, most mains powered broadcast receivers were operated with electro-dynamic loadspeakers with their field excited by a field coil driven by direct current. In most AC powered receivers, the mains voltage was stepped up by a transformer to a secondary voltage of around 385-0-385 AC to feed a full wave rectifier. The rectified output was fed through a ripple filter of two shunt electrolytic capacitors and a series inductance or choke. The choke was formed by the field coil of the speaker which was also excited by the direct current passing through it. The DC high tension voltage from the output of the filter, and fed to the valve circuitry, was usually around 250 V.



Typical AC powered Receiver with the Speaker Field Coil as the Filter Inductor

In converting to DC operation, we had no need for rectification. However a lot of noise interference came in from the mains, probably commutator noise from all the DC electric motors across the lines and perhaps some noise also generated at the power station itself. So there was a need for some form of filter in feeding the valve circuits directly from the 230 volt DC mains. Speaker field coils were around 1000 ohms or higher. Had one of these been connected in series with the valve circuit load, as in the original AC circuit, we would have lost a lot of high tension voltage, resulting in a value high well below the original 250V.

To provide an inductance for the mains noise filter, we made use of one of the lower resistance windings of the transformer, which Alan decided should be left fitted in place. His line of thinking was that one day Murray Bridge might get AC mains distribution and he might just be the one responsible for converting many of these receivers back to AC. With the same thoughts in mind, he stored away the rectifier valves and the 6.3V heater output valves which had been removed. These could be re-used in the event of modification back to AC. As it turned out, his vision of AC for the town was right and by 1954, ETSA had extended their AC grid to Murray Bridge.

Although it was some 70 years ago, I remember well the process of conversion to DC. However I am a little bit hazy on exactly how we excited the speaker field coil. But I feel sure we must have connected it via a series power resistor directly to the DC mains. The amount of current necessary to excite the field was not critical. Let's assume 50v would be sufficient across the 1000 ohm coil, then we could achieve that with a 3600 ohm series resistor rated for 10 watts. A vitreous enamel resistor of that rating would have been easily available as an "off the shelf" item.

The problem of the mains negative outer pole

As explained earlier, consumer loads were connected alternately to a positive and negative outer pole. For a negative outer pole, the cathode end of the valve circuitry (or the negative rail) had to be connected to that negative outer pole, 230 V referenced to the neutral wire near earth potential. Some radio receivers made specifically for DC mains or AC/DC operation floated both the negative and positive rails with no connection to the receiver metal chassis. However the receivers designed initially for AC operation used the chassis as the base for the negative rail. To float the negative rail on these receivers would have been a major rewire job. So connected to the negative outer pole, the chassis was operated at high DC voltage. To service these receivers connected to a negative outer pole, was indeed a hazardous job. Fortunately in our case, Alan's shop and workshop, were connected to the positive outer pole.

Some receiver cabinets had open backs. So another part of the conversion was to fit a plywood back to the cabinet to protect the user from the "hot" chassis. It is interesting that in that era, most of the houses I saw in Murray Bridge (including that of my parents) had their power outlets wired with two pin outlets with no connection to earth. Maybe they caught up with this and put in three pin outlets, with a pin for earth, when the town converted to AC mains in 1954.

The two pin plugs had one little advantage on the DC mains. When plugging the receiver into the two pin outlet, one expected that it might not work. If it didn't, it was assumed that the power was connected in reverse polarity and the two pin plug was taken out and inserted the opposite way. Of course the connection of the receiver valve circuitry to the DC mains was polarised and the receiver would only work with the plug inserted in one of the two possible ways.

The problems of DC Mains for the Radio Amateur

At the time we had the DC mains in Murray Bridge there were several radio amateurs, including myself, who operated in the town from those mains. In those days we essentially built all our own transmitting gear. But there were several problems in designing that gear.

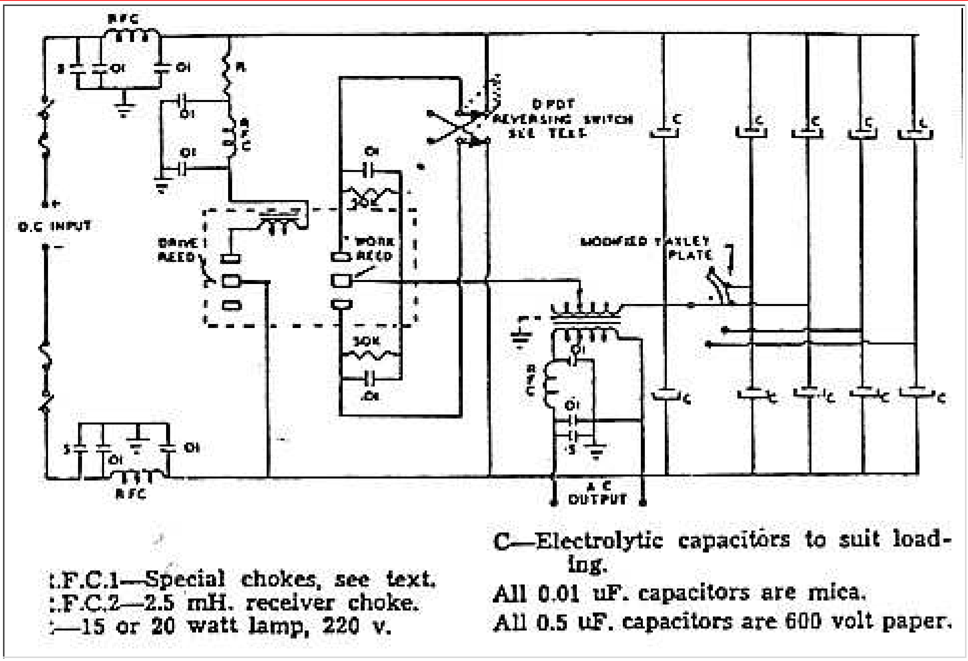
The first problem was the one of safety when the particular house was fed with a negative outer pole. As described concerning the broadcast receivers, if the valve circuitry was then operated direct from the DC mains, the negative rail had to be isolated from ground and any part of the metal housing connected to ground.

The second problem concerned supply for valve heaters. On AC mains, a step down transformer was normally used, but on DC this option was not available. On receivers, heaters were generally operated in a constant current series heater chain (typically 0.3. amp). For transmitting valves, that was not always practical as transmitting type valves were often directly heated. Also the filament or heater current was usually a lot higher than the 0.3A discussed before. Connected in a series chain via a resistor to the 230V DC mains, the circuit could consume a lot of power. In my transmitter, I used a number of valves type 807 whose heater operated at 6.3 volts and 0.9 amps. At that current, the series circuit would have consumed 200 watts from the mains and and required a series resistance of high power rating.

The third problem was the limitation in plate voltage available. To transmit, using input powers approaching 100 watts, some 600 to 800 volts was normally required at the final amplifier plates and operation from only 230 volts amounted to a severe restriction in output power. For example the 807 needed to be operated at 750 volts to get maximum power output possible.

Various methods were applied to cope with some of these problems. Frank Miller VK5BF had both mains outer poles wired to his house so that he was able to apply 460 volts to his final amplifier stage. He had his transmitter in a large metal rack and he must have gone to a lot of trouble to isolate his negative rails from the metal work.

The house where Bill Rice VK5BP/ (later VK3ABP) lived had a negative mains outer. This provided some incentive for him to build a vibrator switched DC to AC inverter, a device somewhat difficult to get going satisfactorily because of the electrical interference created by the high voltage vibrator contacts. The inverter transformer provided electrical isolation of the mains from his negative high tension line (and chassis). The inverter also provided the AC source which could be transformed to the required voltage levels within the transmitter. If we could have used the technology of today, a suitable solid State inverter would have been obtained. However in the era under discussion, the transistor and solid circuit circuitry hadn't been developed.



DC-AC Vibrator Inverter by Eric Cornellius
The basis of the Inverter built by Bill Rice VK5BP

I initially had my transmitter operating in Blair Athol from the AC mains in Adelaide. I also used a low power rig at my parents home in Murray Bridge where I regularly visited. But I ultimately returned the AC powered transmitter rack to Murray Bridge and faced the problems of powering from DC.

To get an AC source I rewound a genemotor as a DC-AC rotary converter. This provided sufficient power to supply the valve heaters, but not enough to power the transmitter high tension supplies, designed to operate from the AC mains. So I still had to operate with 230 volt DC for high tension and hence limited power output. But the rotary converter eventually developed a winding fault which then put it out of action. By that time, Bill Rice had moved to Adelaide and his transmitter was then operated from the Adelaide AC mains. Bill no longer needed his inverter, so it was was pressed into service to supply my transmitter with sufficient AC power.

Summary

The discussion goes back 70 years when towns in South Australia were essentially powered from locally generated Direct Current (DC) generators. But Sir Tom Playford came along and his Government nationalised all the electricity supplies for the State. The Electricity Trust of South Australia (ETSA) was born and it spread its power lines all over the State. The DC power systems in the towns were taken over and ultimately replaced with power from the ETSA AC grid. I particularly refer to the changes which occurred in the town of Murray Bridge.

But in 1998, the State power network was sold to private interests.

Further discussion concentrates on the servicing of broadcast receivers working on the DC mains and the modifications to convert to DC receivers made for the operation on AC mains. Various design problems were discussed including a safety issue when working on a receiver connected to the negative outer wire.

My final paragraphs relate to amateur radio and describe some of the things we did to get our home built transmitters working from the DC mains. This section was a repeat of what I had previously included in an article of "Amateur Radio", July 1988 (Ref:1).

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