Design of a prime-focus feed with backward radiation

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Abstract. *This paper describes the design of a highly effective parabolic dish antenna primary feed based on backward radiation. This assembly, comprising a dielectric lens and reflecting plate, supports both linear and circular polarization and may be directly attached to a circular waveguide. The current design is intended to work in the 10 GHz band with the specified parabolic dish antenna.*

Keywords

Parabolic dish antenna, primary focus feed, dielectric lens, circular polarization

Introduction

The objective of this paper is to describe the design of a prime-focus feed for a 60cm diameter parabolic dish antenna with f/D ratio 0.285 (subtended angle 171°) for a frequency of 10.368 GHz. The main advantage of this feed configuration is improved dish antenna efficiency with a very simple mechanical setup.

Design goals were:

- Linear / circular polarization capabilities
- Good axial ratio (with CP)
- Low cross-polarization losses
- -13 dB dish edge taper for low side lobes
- Suitable radiation pattern with suppression in the longitudinal direction to minimize blockage effects

Based on these considerations, a lens structure affixed to a circular waveguide was proposed (Fig. 1). This design comes from the so-called “hat-feed” [1], however; it has been substantially modified to match our electrical and system requirements.

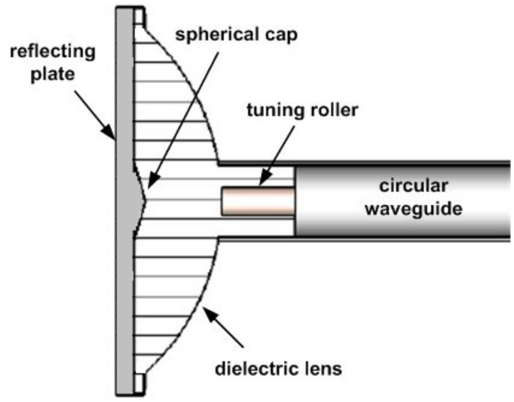

Fig. 1. Proposed design of the feed

1. Feed design

The feed consists of a relatively small number of parts (Fig. 1):

- dielectric lens with spherical cap made of TEFLON™
- Circular waveguide to provide transition with tuning roller and dielectric lens
- Metal reflecting plate

The circular waveguide has been designed to support propagation of fundamental TE_{11} mode only, at a center frequency f_0=10.368 GHz. This prompts one to specify a readily available cylinder with inner radius 10 mm for the waveguide.

2. Tuning the feed parameters

To investigate the performance effects of the designed feed parameters, parametric simulations were performed using full-wave EM simulator CST Microwave Studio [2]. The model of the assembly was fed by a waveguide port excited by pure circular polarization (two orthogonal TE_{11} modes shifted by 90° at center frequency).

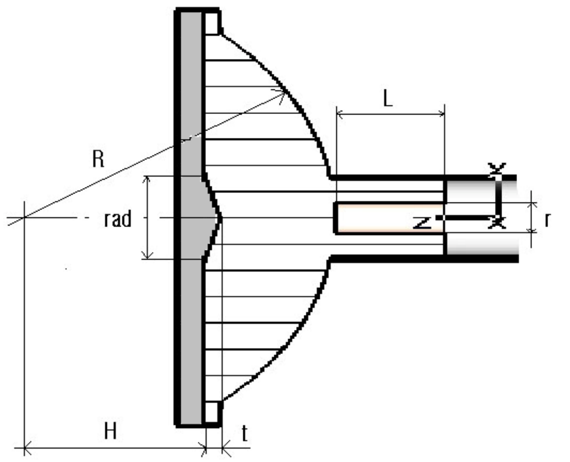

Fig. 2. Design parameters

The effect of tuning the feed's parameters is shown in Tab. 1, where AR denotes Axial Ratio.

Parameter	Pattern	Matching	AR
L	+	+++	N/A
r	+	+++	N/A
t	++	+++	++
H	+++	+++	+++
rad	+	++	+
R	+++	+++	+++

Tab. 1. Effect of tuning variables on feed performance

It was observed that the dielectric transition could be tuned (within TE_{11} band) by varying *L*, *r* and *t* parameters (see Fig. 2) while radiation parameters remain almost unchanged.

Illumination of the dish and Axial Ratio are controlled by selection of the *H* and *R* parameters.

3. Feed performance

After many parametric simulations, the feed was tuned at a frequency 10.368 GHz and its radiation properties were adjusted to properly illuminate the given dish. The radiation patterns of the feed excited with circularly polarized mode TE_{11} modeled in CST-MWS are shown in Fig. 3 and Fig. 4.

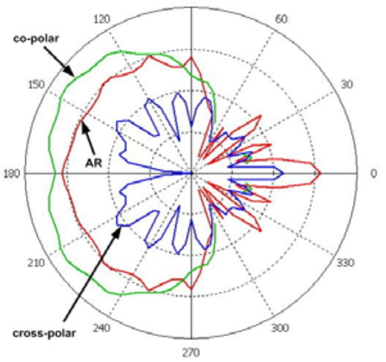

Fig. 3. Polar radiation pattern cut showing co- and cross-polarizations and AR

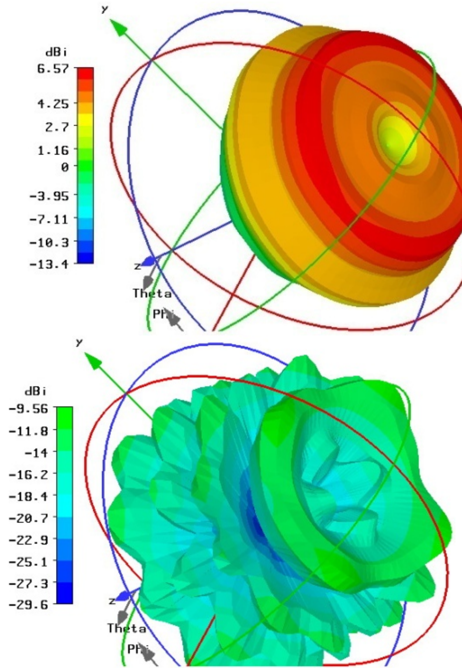

Fig. 4. Full 3D radiation patterns of co- (top) and cross- (bottom) polarizations.

Return Loss (S_{11} parameter) at the designed frequency is better than 25 dB. See Fig. 9

Due to the lack of the time, actual operating feed measurements were made using linear polarization only. To operate this feed with circular polarization, a longer waveguide and polarizer (i.e. septum polarizer [3], [4]) must be added. CP measurements are planned in the near future.

For linear polarization measurements, a very simple coaxial-to-waveguide transition consisting of the inner pin of a SMA connector positioned within the circular waveguide was used. This transition was tuned for best impedance match at 10.368 GHz. The overall modified assembly is shown in Fig. 5.

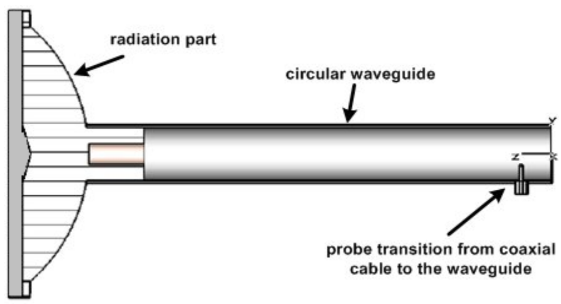

Fig. 5. Complete feed assembly with coaxial-to-waveguide transition

Relative bandwidth of the entire feed in free space is approximately 3% for $S_{11} < -20$dB.

As discussed above, the feed assembly was measured in an anechoic chamber and E/H plane cuts were evaluated. See Fig. 6 and Fig.7. Excellent agreement between modeled and measured parameters was observed.

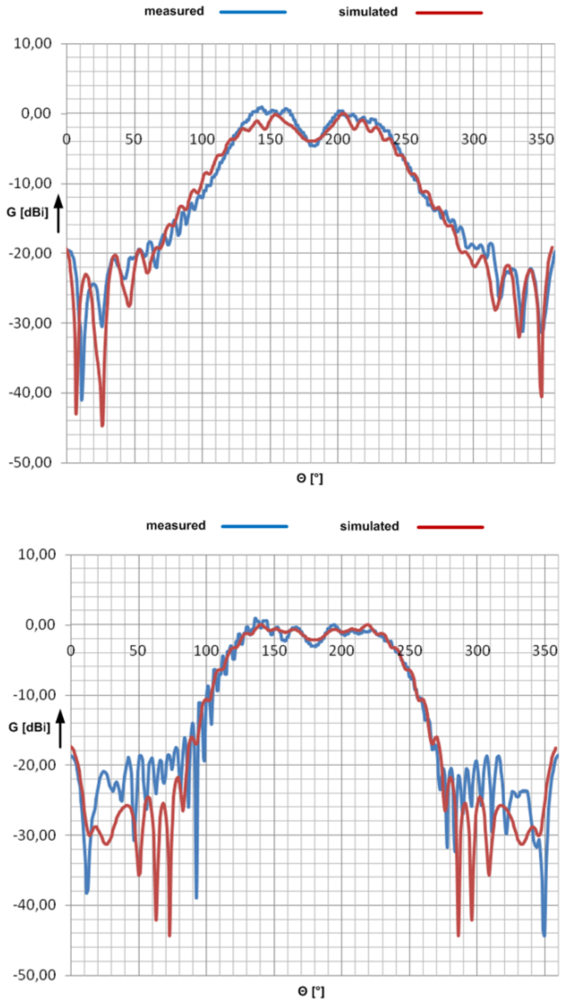

Fig. 6. E plane (top) and H plane (bottom) farfield co-polar cuts, comparison of measured and simulated data.

Finally, simulation of the entire system (feed+dish) has also been performed in CST-MWS. Despite the very large size of the modeled electrical system (dish diameter is 20λ), it was possible to run the simulation with good accuracy in T-solver. Because we used a full-wave simulation, it was possible to take into account all the negative factors that can downgrade the antenna performance . We calculated the entire system with the feed excited with both, linear and circular polarization. Measured radiation patterns for linear polarization and their comparison with calculated data are shown in Fig. 8

Very good separation of approximately 40 dB between co- and cross- polarization in the main lobe was achieved. See Fig 10. Simulated directivity D_{sim} was 33.87 dBi.

Theoretical maximum directivity of the entire system with constant illumination can be calculated from equation

$$D_{teor} = 20 \log \frac{\pi D}{\lambda} = 36.278 \text{ dBi}, \quad (1)$$

where D is dish diameter and λ is wavelength.

The calculated efficiency of the entire system is 57.4% while the measured result indicates actually efficiency about 15 % higher.

Fig. 7 Antenna assembly measured in anechoic chamber

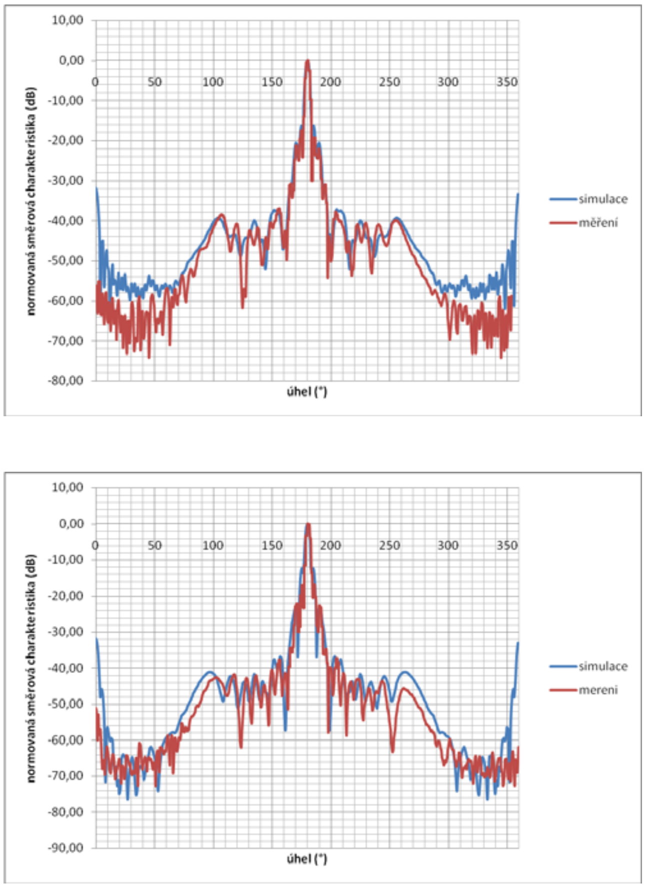

Fig. 8. Antenna radiation pattern. E plane (top) and H plane (bottom)

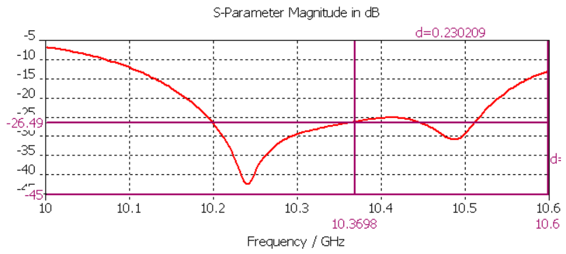

Fig. 9 Calculated S11 feed parameters

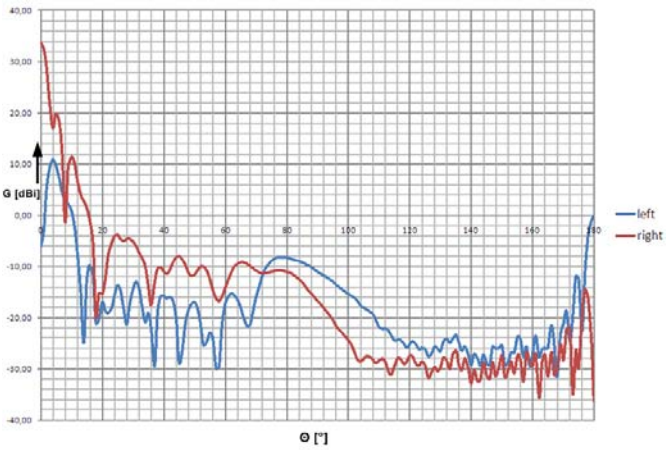

Fig. 10. Simulated co- and cross- polar radiation pattern of the feed + dish system

Conclusions

The designed feed exhibits very good performance parameters in all important areas for both linear and especially for circular polarization. The total efficiency achieved for this very deep dish parabolic antenna is excellent and the impedance match is also very good.

The feed dimension are in Appendix 1

References

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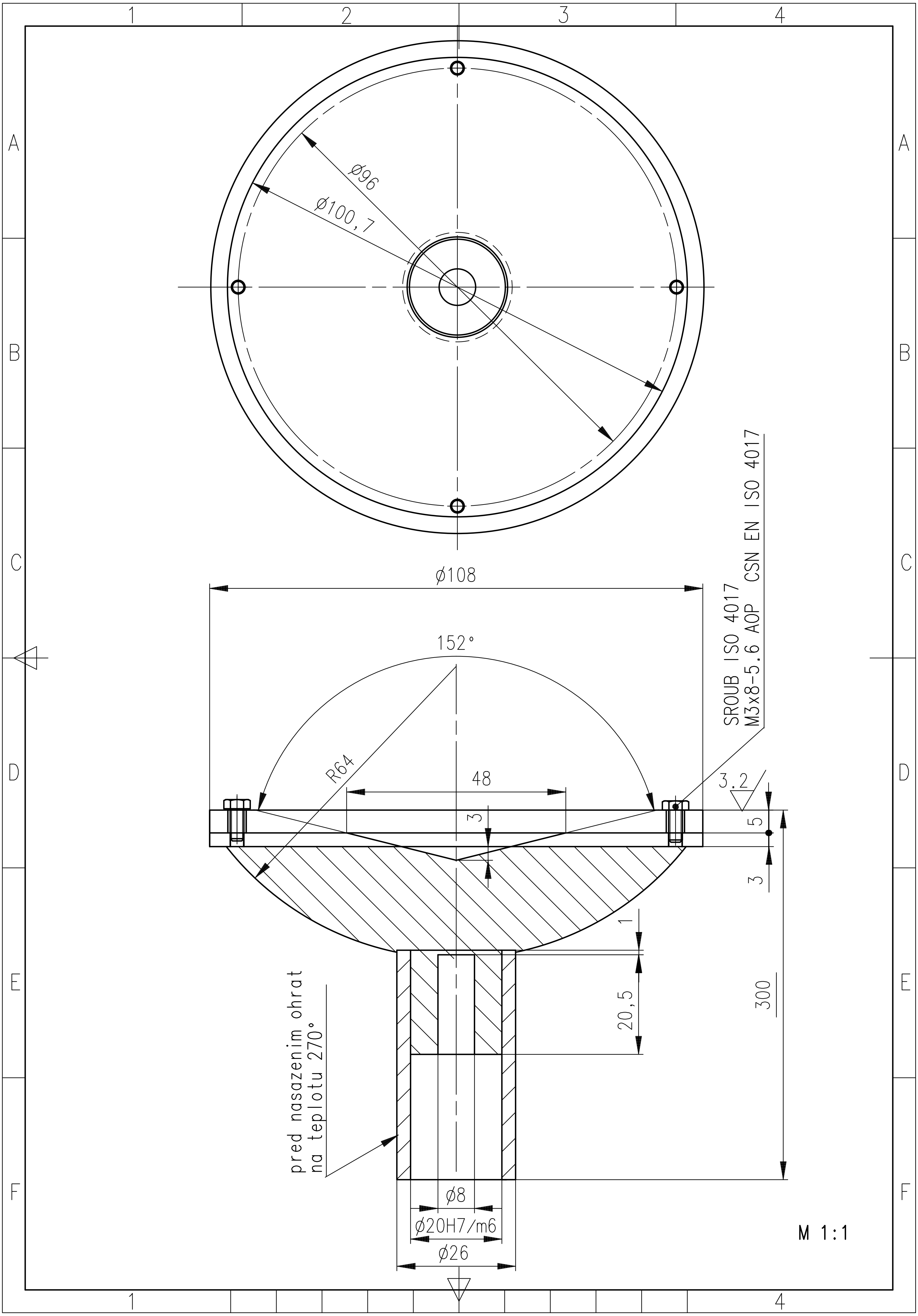

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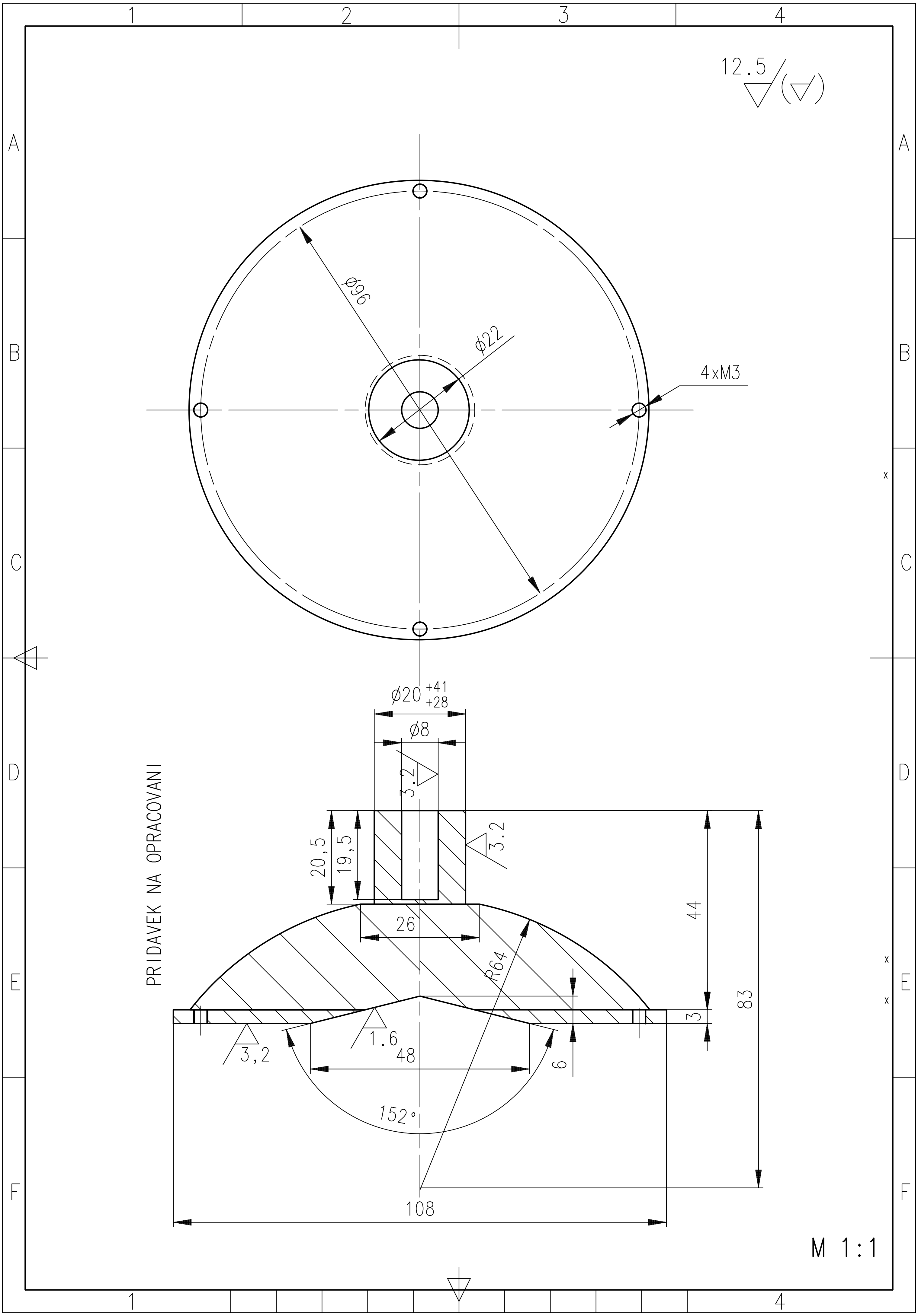
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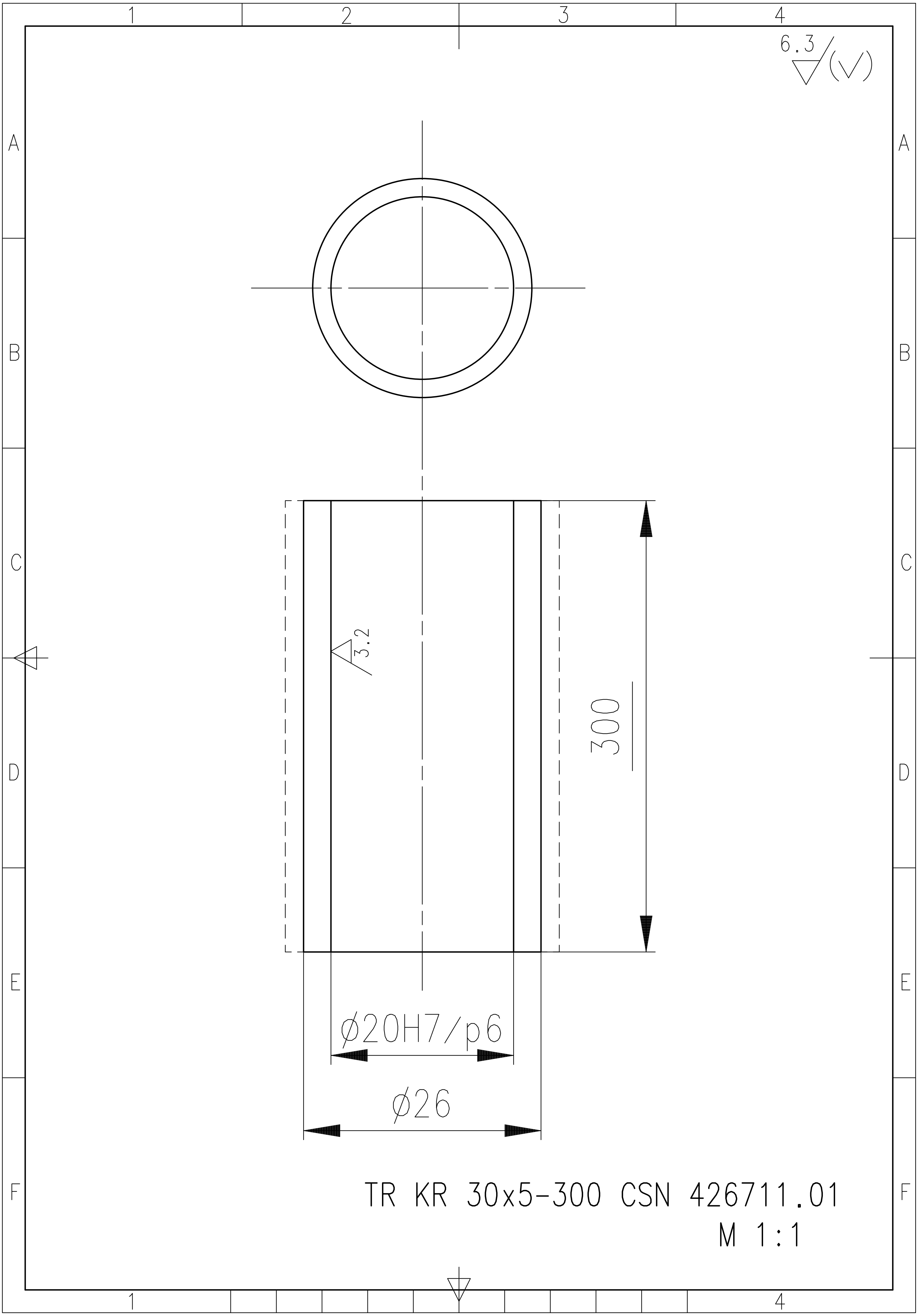
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